



INDIAN AGRICULTURAL  
RESEARCH INSTITUTE, NEW DELHI

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# CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 43

July 1, 1943—June 30, 1944

With Administrative Reports through December 15, 1944



CARNEGIE INSTITUTION OF WASHINGTON

WASHINGTON, D. C.

1944

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## PRESIDENT AND TRUSTEES

### PRESIDENT

VANNEVAR BUSH

### BOARD OF TRUSTEES

W. CAMERON FORBES, *Chairman*  
WALTER S. GIFFORD, *Vice-Chairman*  
FREDERIC A. DELANO, *Secretary*

THOMAS BARBOUR  
JAMES F. BELL  
ROBERT WOODS BLISS  
LINDSAY BRADFORD  
FREDERIC A. DELANO  
HOMER L. FERGUSON  
W. CAMERON FORBES  
WALTER S. GIFFORD

HERBERT HOOVER  
FRANK B. JEWLT  
ERNEST O. LAWRENCE  
ALFRED L. LOOMIS  
ROSWELL MILLER  
HENRY S. MORGAN  
SLELEY G. MUDD  
HENNING W. PRENTIS, JR.

ELIHU ROOT, JR.  
HENRY R. SHEPLEY  
RICHARD P. STRONG  
CHARLES P. TAFT  
JUAN T. TRIPPE  
JAMES W. WADSWORTH  
FREDERIC C. WALCOTT  
LEWIS H. WEEED

### *Executive Committee*

W. CAMERON FORBES, *Chairman*

ROBERT WOODS BLISS  
VANNEVAR BUSH

FREDERIC A. DELANO  
WALTER S. GIFFORD  
HENRY R. SHEPLEY

FREDERIC C. WALCOTT  
LEWIS H. WEEED

### *Finance Committee*

FREDERIC C. WALCOTT, *Chairman*

LINDSAY BRADFORD  
WALTER S. GIFFORD

HENNING W. PRENTIS, JR.  
ELIHU ROOT, JR.

### *Auditing Committee*

FREDERIC A. DELANO, *Chairman*

ROBERT WOODS BLISS

JAMES W. WADSWORTH

## STANDING COMMITTEES FOR THE YEAR 1945

### *Committee on Astronomy*

HERBERT HOOVER, *Chairman*

WALTER S. GIFFORD  
ROSWELL MILLER

SLELEY G. MUDD  
ELIHU ROOT, JR.

### *Committee on Terrestrial Sciences*

FRANK B. JEWLT, *Chairman*

FREDERIC A. DELANO  
HOMER L. FERGUSON

HENRY S. MORGAN  
FREDERIC C. WALCOTT

### *Committee on Biological Sciences*

LEWIS H. WEEED, *Chairman*

THOMAS BARBOUR  
JAMES F. BELL

ERNEST O. LAWRENCE  
HENNING W. PRENTIS, JR.

### *Committee on Historical Research*

HENRY R. SHEPLEY, *Chairman*

ROBERT WOODS BLISS  
RICHARD P. STRONG

CHARLES P. TAFT  
JAMES W. WADSWORTH

## FORMER PRESIDENTS AND TRUSTEES

### PRESIDENTS

DANIEL COIT GILMAN, 1902-04  
JOHN CAMPBELL MERRIAM, *President* 1921-38; *President Emeritus* 1939-

ROBERT SIMPSON WOODWARD, 1904-20

### TRUSTEES

ALEXANDER AGASSIZ	1904-05	WAYNE MACVEAGH	1902-07
GEORGE J. BALDWIN	1925-27	ANDREW J. MELLON	1924-37
JOHN S. BILLINGS	1902-13	DARIUS O. MILLS	1902-09
ROBERT S. BROOKINGS	1910-29	S. WEIR MITCHELL	1902-14
JOHN L. CADWALADER	1903-14	ANDREW J. MONTAGUE	1907-35
WILLIAM W. CAMPBELL	1929-38	WILLIAM W. MORROW	1902-29
JOHN J. CARTY	1916-32	WILLIAM CHURCH OSBORN	1927-34
WHITEFOORD R. COLE	1925-34	JAMES PARMELLE	1917-31
CLEVELAND H. DODGE	1903-23	WM. BARCLAY PARSONS	1907-32
WILLIAM E. DODGE	1902-03	STEWART PATON	1916-42
CHARLES P. FENNER	1914-24	GEORGE W. PEPPER	1914-19
SIMON FLEXNER	1910-14	JOHN J. PERSHING	1930-43
WILLIAM N. FREW	1902-15	HENRY S. PRITCHETT	1906-36
LYMAN J. GAGE	1902-12	ELIHU ROOT	1902-37
CASS GILBERT	1924-34	JULIUS ROSENWALD	1929-31
FREDERICK H. GILLETT	1924-35	MARTIN A. RYERSON	1908-28
DANIEL C. GILMAN	1902-08	THEOBALD SMITH	1914-34
JOHN HAY	1902-05	JOHN C. SPOONER	1902-07
MYRON T. HERRICK	1915-29	WILLIAM BENSON STOREY	1924-39
ABRAM S. HEWITT	1902-03	WILLIAM H. TAFT	1906-15
HENRY L. HIGGINSON	1902-19	WILLIAM S. THAYER	1929-32
ETHAN A. HITCHCOCK	1902-09	CHARLES D. WALCOTT	1902-27
HENRY HITCHCOCK	1902-02	HENRY P. WALCOTT	1910-24
WILLIAM WIRT HOWE	1903-09	WILLIAM H. WELCH	1906-34
CHARLES L. HUTCHINSON	1902-04	ANDREW D. WHITE	1902-03
WALTER A. JESSUP	1938-44	EDWARD D. WHITE	1902-03
SAMUEL P. LANGLEY	1904-06	HENRY WHITE	1913-27
CHARLES A. LINDBERGH	1934-39	GEORGE W. WICKERSHAM	1909-36
WILLIAM LINDSAY	1902-09	ROBERT S. WOODWARD	1905-24
HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902-08
SETH LOW	1902-16		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

## STAFF OF INVESTIGATORS FOR THE YEAR 1944

### ASTRONOMY

#### MOUNT WILSON OBSERVATORY

Organized in 1904; George E. Hale, Director 1904-1923, Honorary Director 1923-1936

WALTER S. ADAMS, *Director*

ALFRED H. JOY, *Secretary*

WALTER BAADE

HAROLD D. BABCOCK

WILLIAM H. CHRISTIE

THEODORE DUNHAM, JR.

JOSEPH O. HICKOX

EDISON HOGE

EDWIN P. HUBBLE

MILTON L. HUMASON

ROBERT B. KING

PAUL W. MERRILL

RUDOLPH MINKOWSKI

SETH B. NICHOLSON

EDISON PETTIT

ROBERT S. RICHARDSON

ROSCOE F. SANFORD

GUSTAF STROMBERG

ADRIAAN VAN MAANEN

OLIN C. WILSON

RALPH E. WILSON

### TERRESTRIAL SCIENCES

#### GEOPHYSICAL LABORATORY

Organized in 1906, opened in 1907, Arthur L. Day, Director 1909-1936

LEONARD H. ADAMS, *Director*

JOHN S. BURKE

JOSEPH L. ENGLAND

RALPH E. GIBSON

ROY W. GORANSON

JOSEPH W. GRIGG

EARL INGERSON

FRANK C. KRACEK

ORVILLE H. LOEFFLER

HERBERT E. MERWIN

GEORGE W. MORFY

ELBURT F. OSBORN

CHARLES S. PIGGOT

EUGENE POSNIK

HOWARD S. ROBERTS

JOHN F. SCHAFER

EARNEST S. SHEPHERD

GEORGE TUNELL

WILLIAM D. URRY

\*FRANK E. WRIGHT

EMANUEL G. ZIES

### DEPARTMENT OF TERRESTRIAL MAGNETISM

Organized in 1904; Louis A. Baer, Director 1904-1929

JOHN A. FLEMING, *Director*

OLIVER H. GISH, *Assistant Director*

LLOYD V. BERKNER

EDWIN J. CHERNOSKY

DFAN B. COWIE

SCOTT E. FORBUSH

ALBERT A. GIESEKES, JR.

GEORGE K. GREEN

LAWRENCE R. HAFSTAD

NORMAN P. HEYDENBURG

ELLIS A. JOHNSON

HENRY F. JOHNSTON

MARK W. JONES

PAUL G. LEDIG

ALVIN G. McNISH

WILLIAM C. PARKINSON

RICHARD B. ROBERTS

WILLIAM J. ROONEY

WALTER E. SCOTT

STUART L. SEATON

KENNETH L. SHERMAN

WILLIAM F. STEINER

Oscar W. TORRESON

MERLE A. TUVE

ERNST H. VESTINE

GEORGE R. WAIT

HARRY W. WELLS

\* Retired in 1944.

## BIOLOGICAL SCIENCES

### DIVISION OF PLANT BIOLOGY

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

HERMAN A. SPOEHR, *Chairman*  
JENS C. CLAUSEN  
GARRETT J. HARDIN  
WILLIAM M. HIESEY  
DAVID D. KECK  
WINSTON M. MANNING

EMMETT V. MARTIN  
HAROLD W. MILNER  
FORREST SHREVE  
JAMES H. C. SMITH  
HAROLD H. STRAIN

### DEPARTMENT OF EMBRYOLOGY

Organized in 1914; Franklin P. Mall, Director 1914-1917; George L. Streeter, Director 1918-1940

GEORGE W. CORNER, *Director*  
ROBERT K. BURNS, JR.  
LOUIS B. FLEXNER

CHESTER H. HEUSER, *Curator of the Embryological Collection*  
MARGARET R. LEWIS  
SAMUEL R. M. REYNOLDS

### DEPARTMENT OF GENETICS

Station for Experimental Evolution, opened in 1904, combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934; Albert F. Blakeslee, Director 1935-1941.

MILISLAV DEMEREC, *Director*  
UGO FANO  
BERWIND P. KAUFMANN  
EDWIN C. MACDOWELL  
BARBARA MCCLINTOCK

JAMES S. POTTER  
\*OSCAR RIDDLE  
†MORRIS STUGGERDA  
HARRY E. WARMKE

### NUTRITION LABORATORY

Organized in 1907, opened in 1908; Francis G. Benedict, Director 1907-1937  
THORNE M. CARPENTER, *Director*  
V. COROPATCHINSKY

ROBERT C. LEE

### HISTORICAL RESEARCH

#### DIVISION OF HISTORICAL RESEARCH

Department of Historical Research organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

ALFRED V. KIDDER, *Chairman*

#### Section of Aboriginal American History

SYLVANUS G. MORLEY  
EARL H. MORRIS  
HARRY E. D. POLLOCK  
TATIANA PROSKOURIAKOFF  
KARL RUPPERT  
ANNA O. SHEPARD  
EDWIN M. SHOOK  
A. LEDYARD SMITH  
ROBERT E. SMITH  
GUSTAV STRÖMSVIK  
SOL TAX  
J. ERIC S. THOMPSON  
ALFONSO VILLA R.

#### Section of Post-Columbian American History

ELEANOR B. ADAMS  
ROBERT S. CHAMBERLAIN  
RALPH L. ROYS  
FRANCE V. SCHOLES  
LEO F. STOCK

#### Section of the History of Science

GEORGE SARTON  
ALEXANDER POGO

\* Retired in 1944.

† Resigned in 1944.

## RESEARCH ASSOCIATES

### RESEARCH ASSOCIATES ENGAGED IN POST-RETIREMENT STUDIES

ALBERT F. BLAKESLEE, Genetics

GEORGE L. STREIFER, Embryology

FREDERICK H. STARES, Astronomy

### RESEARCH ASSOCIATES CONNECTED WITH OTHER INSTITUTIONS

EDWARD L. BOWLES (Massachusetts Institute of Technology), Physics

JOSEPH C. BOYCE (Massachusetts Institute of Technology), Physics

G. BREIT (University of Wisconsin), Physics

DIRK BROUWER (Yale University), Astronomy

JOHN P. BUWALDA (California Institute of Technology), Geology and Paleontology

RALPH W. CHANFY (University of California), Paleobotany

A. H. COMPTON (University of Chicago), Physics

TH. DOBZHANSKY (Columbia University), Genetics

G. GAMOW (George Washington University), Physics

FRANK T. GUCKER, JR. (Northwestern University), Chemistry

ROSS GUNN (United States Naval Research Laboratory), Terrestrial Magnetism

ARTHUR T. HERZIG (Boston Lying-in Hospital), Embryology

VICTOR F. HESS (Fordham University), Physics

A. HOLLAFENDER (National Institute of Health), Genetics

THOMAS H. JOHNSON (Bartol Research Foundation), Physics

S. A. KORFF (Bartol Research Foundation), Physics

E. A. LOWE (The Institute for Advanced Study), Paleography

ROBERT A. MILLIKAN (California Institute of Technology), Physics

S. A. MITCHELL (University of Virginia), Astronomy

T. H. MORGAN (California Institute of Technology), Biology

WALTER H. NEWHOUSE (Massachusetts Institute of Technology), Geophysics

ROBERT REDFIELD (University of Chicago), Anthropology

HENRY N. RUSSELL (Princeton University), Astronomy

H. C. SHERMAN (Columbia University), Nutrition

JOEL STEBBINS (University of Wisconsin), Astronomy

CHESTER STOCK (California Institute of Technology), Paleontology

JOHN T. TATE (University of Minnesota), Physics

## OFFICES OF ADMINISTRATION

### *Office of the President*

VANNEVAR BUSH, *President*  
WALTER M. GILBERT, *Executive Officer*  
SAMUEL CALLAWAY, *President's Secretary*

### *Office of Publications and Public Relations*

, *Director*  
AILENE J. BAUER, *Assistant to the Director*  
DOROTHY R. SWIFT, *Editor*

### *Office of the Bursar*

EARLE B. BIESECKER, *Bursar*  
J. STANLEY LINGEBACH, *Assistant Bursar*

### *Investment Office (New York City)*

DEVEREUX JOSEPHS, *Investment Officer*  
PARKER MONROE, *Investment Officer*

## ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use, and in recent years a total of ten million dollars has been paid by the Carnegie Corporation of New York as increase to the Endowment Fund of the Institution. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications and Public Relations provides means for appropriate publication.

## ARTICLES OF INCORPORATION

PUBLIC No. 260. An Act to incorporate the Carnegie Institution of Washington.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership

## ARTICLES OF INCORPORATION

to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinafter referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia,

CARNEGIE INSTITUTION OF WASHINGTON

January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

*Approved, April 28, 1904.*

## BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, December 10, 1937, December 15, 1939, December 13, 1940, and December 18, 1942

### ARTICLE I

#### THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.
2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.
3. No Trustee shall receive any compensation for his services as such.
4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

### ARTICLE II

#### MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee.
2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.
3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

### ARTICLE III

#### OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.
2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

CARNEGIE INSTITUTION OF WASHINGTON

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

ARTICLE IV

EXECUTIVE ADMINISTRATION

*The President*

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

## BY-LAWS OF THE INSTITUTION

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

### ARTICLE V

#### COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication. The Executive Committee shall have power to authorize the purchase, sale, exchange, or transfer of real estate.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expend-

## CARNEGIE INSTITUTION OF WASHINGTON

itures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

## ARTICLE VI

### FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

## ARTICLE VII

### AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

## ABSTRACT OF MINUTES OF THE FORTY-SIXTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in New York, N. Y., in the Board Room of the Carnegie Corporation of New York, on Friday, December 15, 1944. It was called to order at 11:20 A.M. by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: James F. Bell, Robert Woods Bliss, Lindsay Bradford, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Frank B. Jewett, Alfred L. Loomis, Roswell Miller, Henry S. Morgan, Seeley G. Mudd, Henning W. Prentis, Jr., Elihu Root, Jr., Henry R. Shepley, Richard P. Strong, Charles P. Taft, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Vannevar Bush, was also in attendance.

The minutes of the forty-fifth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

Upon motion it was

*Resolved*, That the Board of Trustees of the Carnegie Institution of Washington expresses its deep appreciation to the Trustees of the Carnegie Corporation of New York for financial support of the research program of the Institution granted in recent years by the Corporation, with special reference to the liberal addition of \$5,000,000 to the Endowment Fund of the Institution. Such substantial encouragement has enabled the Institution to meet emergency needs and will permit plans for continuation and extension of research activities which have direct application in development of new knowledge for the improvement of mankind, the purpose for which the Institution was founded.

The following appropriations for the year 1945 were authorized:

Pension Fund	\$75,000
Administration (including expenses of Investment Office and of Insurance)	128,492
Publications (including expenses of Office of Publications and Public Relations)	48,700
Departmental Research Operations	964,468
	<hr/>
	\$1,216,660

The Chairman reported the death of Walter A. Jessup and the retirement of John J. Pershing. As a result of balloting, Ernest O. Lawrence, Professor of Physics of the University of California, and Juan T. Trippe, President of Pan American Airways, were unanimously elected to fill existing vacancies in the Board.

Walter S. Gifford and Frederic C. Walcott were re-elected members of the Executive Committee for a period of three years, and Robert Woods Bliss was elected to succeed Dr. Jessup as a member of this committee for the term ending in 1945. Lindsay Bradford and Henning W. Prentis were re-elected members of the Finance Committee for a period of three years.

The meeting adjourned at 1:00 P.M.



## REPORT OF THE EXECUTIVE COMMITTEE

FOR THE YEAR ENDING OCTOBER 31, 1944

*To the Trustees of the Carnegie Institution of Washington:*

**GENTLEMEN:** Article V, section 3 of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, section 3 provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1944.

During this year the Executive Committee held five meetings, printed reports of which have been mailed to each Trustee and constitute a part of this report. Attention is called to the following resolution authorized at the meeting of March 16, 1944, concerning addition of \$5,000,000 to the Endowment Fund of the Institution:

*Resolved*, That the Executive Committee of the Carnegie Institution of Washington desires to express to the Trustees of the Carnegie Corporation of New York its sincere appreciation of their action in providing a substantial addition to the Endowment Fund of the Institution. This liberal grant will enable the Carnegie Institution to meet the future with confidence in its ability to maintain the integrity of its organization, and to provide for future achievements in research.

A statement of activities of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. Increasing requests for use of facilities and resources of the Institution in carrying on war research under contracts with the Government have resulted in full-time operation of many departments of the Institution in the national interest. The detailed estimate of expenditures for the succeeding year contained in the report of the President has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1945, and budget recommendations are based upon the judgment of these Committees with respect to financial policy during the present national emergency.

The Board of Trustees, at its meeting of December 7, 1943, appointed Price, Waterhouse and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1944. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1944, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1944, showing funds available for expenditure

and amounts allotted by the Executive Committee, a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, and a schedule of real estate and equipment at original cost. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

Two vacancies exist in the membership of the Board of Trustees by reason of the retirement of John J. Pershing, and of the death of Walter A. Jessup on July 5, 1944. Nominations to fill vacancies have been requested, received, and distributed in accordance with provisions of the By-Laws, and such nominations will be submitted to the Board at its meeting on December 15, 1944.

The death of Dr. Jessup leaves a vacancy in the Executive Committee. Tenure of office of Messrs. Gifford and Walcott as members of the Executive Committee and of Messrs. Bradford and Prentis as members of the Finance Committee expire at the annual meeting.

W. CAMERON FORBES, *Chairman*  
VANNEVAR BUSH  
FREDERIC A. DELANO  
WALTER S. GIFFORD  
HENRY R. SHEPLEY  
FREDERIC C. WALCOTT  
LEWIS H. WEED

*November 1, 1944*

FINANCIAL STATEMENT FOR FISCAL YEAR ENDING OCTOBER 31, 1944

	Balances unallotted Oct. 31, 1943	Trustees' appropriations Dec. 7, 1943	Transfers and other credits	Total available	Executive Committee allotments	Transfers by Executive Committee	Unallotted balances Oct. 31, 1944
<b>Departmental Research Operations:</b>							
Embryology.....	...	\$71,940	...	\$71,940.00	\$71,940.00	...	...
Genetics.....	...	114,470	\$3,000 00	122,470 00	122,470.00	...	...
Nutrition Laboratory.....	...	19,490	...	19,490 00	19,490.00	...	...
Geophysical Laboratory .....	...	141,106	...	141,106 00	141,106.00	...	...
Historical Research.....	...	112,423	600 00	113,023 00	113,023.00	...	...
Mount Wilson Observatory .....	...	198,550	600.00	199,150 00	199,150.00	...	...
Plant Biology.....	...	61,240	1,500 00	62,740.00	62,740.00	...	...
Terrestrial Magnetism.....	...	208,120	10,960 00	219,080 00	219,080.00	...	...
Research Projects of Limited Tenure	\$8,516 05	4,216 60	12,732 65	500 00	500.00	...	\$12,232.65
Publication.....	22,417 17	18,060	8,456 06	48,933 23	48,407 38	...	\$25.85
Administration.....	130,780	5,500	136,280.00	136,280.00	136,280.00	...	...
Pension Fund.....	60,000	...	60,000 00	60,000 00	60,000 00	...	...
General Contingent Fund .....	5,000	223,219 33	336,235 24	6,000.00	\$222,160 00	...	...
Carnegie Corporation Emergency Fund.....	108,015 91	150,000.00	311,490 15	44,718 00	44,718.00	...	...
	\$161,490.15						
	\$300,439.28	\$1,141,179	\$413,051 99	\$1,854,670 27	\$1,244,904.38	\$222,160.00	\$387,605.89

**AGGREGATE CASH RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1944**

RECEIPTS	DISBURSEMENTS
<i>Securities Sold or Redeemed</i> .....	<i>Securities Purchased</i> .....
Interest from Securities and Bank Balances.....	Accrued Interest on Securities Purchased.....
52,115,120.17	Pension Fund.....
363,769.06	General Reserve Fund.....
52,015.74	Insurance Fund.....
4,043.70	Harriman Fund.....
6,160.62	Special Emergency Reserve Fund.....
13,667,381.24	National Defense Revolving Fund.....
	General Contingent Fund.....
	Carnegie Corporation of New York Emergency Fund.....
	Administration Building and Addition:
	Construction and Site (Old Building).....
	Construction (Addition to Administration Bldg.).....
	Site (Addition to Administration Building).....
	Miscellaneous Expenditures*.....
	<i>Departmental Research Operations:</i>
	Departments of Research, Buildings and Equipment.....
	Departmental Operations.....
	Research Projects of Limited Tenure.....
	Publication.....
	Administration.....
	Employees' U. S. Bond Purchases.....
	National Research Council.....
	Miscellaneous.....
	<i>National Defense Revolving Fund (Refunds and Advances)</i> .....
13,076.02	2,157,099.51
18,021.09	Administration.....
35,450.65	Employees' U. S. Bond Purchases.....
981,126.69	National Research Council.....
	Miscellaneous.....
	<i>Employees' Salary Deductions for the Purchase of U. S. Bonds</i> .....
	October 31, 1944, Cash in Banks.....
	<b>\$160,513,239.39</b>

\* Includes Equipment \$7,206.41, Repairs and Alterations to Old Building \$18,599.29.

**REAL ESTATE AND EQUIPMENT, ORIGINAL COST**

*Administration (October 31, 1944)*

*Washington, D. C.*

Building, site, and equipment.....	\$848,627.84
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*Division of Plant Biology (September 30, 1944)*

*Stanford University, California (Headquarters)*

Buildings and grounds.....	\$74,125.72
Liaboratory.....	40,500.38
Library.....	26,184.33
Operating equipment.....	14,062.14
	<hr/>
	154,872.57

*Department of Embryology (September 30, 1944)*

*Wolfe and Madison Streets, Baltimore, Maryland*

Library.....	\$4,363.05
Laboratory.....	18,988.40
Administration.....	7,989.55
	<hr/>
	31,341.00

*Department of Genetics (September 30, 1944)*

*Cold Sepring Harbor, Long Island, New York*

Buildings, grounds, and field.....	\$292,034.35
Operating equipment.....	33,650.00
Laboratory apparatus.....	37,448.13
Library.....	53,501.16
Archives.....	45,488.90
	<hr/>
	462,122.54

*Geophysical Laboratory (September 30, 1944)*

*2801 Upton Street N.W., Washington, D. C.*

Building, library, and operating appliances.....	\$291,859.42
Laboratory apparatus.....	171,304.96
Shop equipment.....	21,103.00
	<hr/>
	484,267.38

*Division of Historical Research (September 30, 1944)*

*10 Frisbie Place, Cambridge, Massachusetts*

Operating equipment.....	\$28,710.07
Library.....	14,413.87
	<hr/>
	43,123.94

*Nutrition Laboratory (September 30, 1944)*

*29 Blackfan Street, Boston, Massachusetts*

Building, office, shop, and library.....	\$134,513.43
Laboratory apparatus.....	32,611.21
	<hr/>
	167,124.64

*Mount Wilson Observatory (September 30, 1944)*

*Pasadena, California*

Buildings and grounds.....	\$222,458.33
Shop equipment.....	48,051.67
Instruments.....	685,281.21
Furniture and operating appliances.....	149,801.49
Hooker 100-inch reflector.....	638,529.83
	1,744,122.53

*Department of Terrestrial Magnetism (September 30, 1944)*

*5241 Broad Branch Road N.W., Washington, D. C.*

Building, site, and office.....	\$255,931.60
Survey equipment.....	93,512.89
Instruments, laboratory, and shop equipment.....	472,286.90
	<hr/>
	821,731.39
	<hr/>
	\$4,757,333.83

## REPORT OF AUDITORS

*To the Board of Trustees  
Carnegie Institution of Washington  
Washington, D. C.*

We have made an examination of the attached balance sheet of Carnegie Institution of Washington (and supporting schedule of securities owned) as of October 31, 1944 and the related statement of cash receipts and disbursements for the fiscal year then ended. In connection therewith, we obtained confirmations from the custodian, Guaranty Trust Company of New York, as to the securities owned by the Institution and held in safekeeping at October 31, 1944 and from the depositaries as to the cash balances in banks at that date. The interest coupons maturing during the fiscal year on bonds owned were accounted for, and the dividends received during the year on stocks owned were compared with published dividend records. The recorded cash receipts were traced to deposits shown on the bank statements, and paid checks (except checks of recent date aggregating \$66,893 not yet received from the bank and possibly lost in transit) and approved vouchers were inspected in support of the head office disbursements. We did not visit the branch offices of the Institution but we reviewed internal audit reports of the Bursar covering examinations of the branch records during the year and it appeared that the internal audits were satisfactorily conducted. We also inspected certified copies of the minutes of meetings of the Board of Trustees and the Executive Committee with respect to the appropriations and allotments for the year. We have not examined the financial statements of the Institution as of October 31, 1943 and have accepted the balances as of that date as shown in the report of other independent public accountants.

The securities are stated at cost, amortized cost, or value at date acquired. In accordance with a recommendation made in February 1940 by the Institution's Finance Committee, premiums on bonds purchased subsequent to January 1, 1940 are being amortized on a straight-line basis to the dates on which the bonds are first callable or payable at par. The amortization of such premiums applicable to the year ended October 31, 1944 amounted to \$13,080. Real estate and equipment are stated at cost, and books on hand for sale are carried at sales prices. In accordance with accepted practice no provision has been made for depreciation of property owned by the Institution.

In accordance with established custom of the Institution, the budget appropriations are made for the calendar year whereas the annual financial statements are prepared for the fiscal year ending October 31. The balance of income for 1944, applicable to the months of November and December, is accordingly included in the assets of the General Fund at October 31, 1944 and the unexpended appropriations and allotments at that date are reflected in the current obligations shown on the balance sheet.

In our opinion, with the foregoing explanations, the accompanying balance sheet and related statement of cash receipts and disbursements present fairly the position of Carnegie Institution of Washington at October 31, 1944 and the cash transactions for the year ended on that date.

PRICE, WATERHOUSE & Co.

*Washington, D. C.  
November 27, 1944*

BALANCE SHEET OCTOBER 31, 1944

ASSETS		LIABILITIES	
<i>Investments</i>			
Securities . . . . .	\$33,325,043.28	<i>Endowment and Other Funds</i>	
Cash: . . . . .	4,622,513.19	Capital Funds	\$32,000,000.00
Awaiting investment . . . . .	35,573.54	Endowment Fund . . . . .	103,310.80
Reserved for current needs . . . . .		Colburn Fund . . . . .	3,675,028.15
		Capital Reserve Fund . . . . .	
		Harriman Fund (excluding \$179,628.05 included in	
		Property Fund below) . . . . .	
		Teeple Fund . . . . .	347,830.94
			6,160.62
		<i>Special Funds</i>	\$36,132,319.61
		Pension Fund . . . . .	
		General Reserve Fund . . . . .	239,548.84
		Current funds invested (see below) . . . . .	1,111,261.56
		<i>Property Fund</i>	500,000.00
		Income invested . . . . .	\$37,983,130.01
		Harriman property (gift) . . . . .	
		<i>General Fund</i>	
		Current obligations: research operations . . . . .	\$482,986.89
		Research projects of limited tenure . . . . .	44,062.32
		Publication . . . . .	58,536.19
		Administration . . . . .	48,522.66
		General Contingent Fund . . . . .	115,411.90
		Carnegie Corporation Emergency Fund . . . . .	285,896.39
		Employees' U. S. Bond Purchase Fund . . . . .	1,332.65
		Excess of advances received on U. S. Government contracts over disbursements made thereon . . . . .	196,887.99
		National Defense Revolving Fund (includes reimbursable expenditures of \$115,613.32 from U. S. Government carried in accounts receivable, per contra) . . . . .	300,000.00
		Unappropriated balance . . . . .	\$1,533,646.99
			\$1,057.19
		<i>Less</i> Current funds invested (see above) . . . . .	\$1,084,704.18
		Value of publications and invoices . . . . .	500,000.00
		Publication paper in stock . . . . .	170,023.61
			441,03
			\$43,995,632.66

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**STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDED OCTOBER 31, 1944**

RECEIPTS	DISBURSEMENTS
Interest and dividends from securities.....	\$1,302,027.77
Sales of publications.....	5,570.45
Refunds and other credits.....	138,491.51
From other organizations and individuals for specific purposes:	
Carnegie Corporation of New York:	
Endowment.....	5,000,000.00
Other grants.....	168,000.00
Estate of John E. Teeple.....	1,000.00
American Philosophical Society.....	1,000.00
Frank McArthur.....	100.00
Pension Fund (refunds):	
Employees' U. S. bond purchases.....	1,548.61
National Defense Revolving Fund (reimbursements and advances):	
Securities purchased.....	699,963.20
Securities redeemed or sold.....	\$7,317,701.54
	5,169,299.17
	\$12,487,000.71
Cash in banks, November 1, 1943 (including departmental bank balances \$53,807.70).....	983,371.52
	\$13,470,372.23
Accrued interest on securities purchased.....	\$14,155.88
Pension Fund.....	93,790.44
General Contingent Fund.....	6,278.81
Carnegie Corporation Emergency Fund.....	12,730.00
Harriman Fund.....	42.40
Departmental research operations.....	903,720.34*
Research projects of limited tenure.....	41,742.43
General publication.....	19,105.37
Office of Publications.....	15,153.21
Administration.....	132,477.35
National Defense Revolving Fund.....	572,968.36
Employees' U. S. bond purchases.....	34,118.00
	\$1,846,282.59
Securities purchased.....	6,123,959.08
	\$7,970,241.67
Cash in banks, October 31, 1944:	
Uninvested principal:	
Awaiting investment.....	\$4,622,513.19
Reserved for current needs.....	35,573.54
	\$4,658,086.73
Departmental bank balances.....	42,722.79
General account.....	799,321.04
	5,500,130.56
	\$13,470,372.23

\* Includes specific terminating projects administered through departments.

SCHEDULE OF SECURITIES OWNED OCTOBER 31, 1944

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired	Market value	Interest income for year
	UNITED STATES GOVERNMENT BONDS				
\$304,000	U. S. of America Treasury 2s	1951-49	\$304,000.00	\$309,130	\$6,080.00
312,000	U. S. of America Treasury 2s	1951-49	312,000.00	317,070	6,240.00
200,000	U. S. of America Treasury 2s	1952-50	200,000.00	202,875	4,000.00
500,000	U. S. of America Treasury 2s	1954-52	500,000.00	501,875	-165.00
800,000	U. S. of America Treasury 2 1/8s	1955-52	800,000.00	815,750	18,000.00
1,239,000	U. S. of America Treasury 2 1/8s	1954-52	1,244,121.68*	1,287,011	30,975.00
300,000	U. S. of America Treasury 2 1/8s	1958-56	300,000.00	311,156	7,500.00
350,000	U. S. of America Treasury 2 1/8s	1967-62	350,000.00	351,500	8,750.00
75,000	U. S. of America Treasury 2 1/8s	1968-63	75,000.00	75,117	1,875.00
1,200,000	U. S. of America Treasury 2 1/8s	1969-64	1,200,000.00	1,201,125	30,000.00
400,000	U. S. of America Treasury 2 1/8s	1969-64	400,000.00	400,375	7,486.32
50,000	U. S. of America Savings Defense "G" 2 1/8s	1953	50,000.00	47,400	1,250.00
50,000	U. S. of America Savings Defense "G" 2 1/8s	1954	50,000.00	47,800	1,250.00
50,000	U. S. of America Savings Defense "G" 2 1/8s	1954	50,000.00	48,100	1,250.00
100,000	U. S. of America Savings Defense "G" 2 1/8s	1955	100,000.00	96,900	2,500.00
100,000	U. S. of America Savings Defense "G" 2 1/8s	1956	100,000.00	98,800	1,250.00
	Income from bonds sold				
	Total U. S. Government		\$6,035,121.68	\$6,112,34	\$141,804.12
	FOREIGN BONDS				
\$90,000	Canadian National Ry. Co. 4 1/8s Guar.	1951	\$90,256.14*	\$100,800	\$4,050.00
100,000	Canadian National Ry. Co. 4 1/8s Guar.	1957	112,000.00	116,000	4,500.00
57,000	Canadian National Ry. Co. 5s Guar.	1969	61,933.32*	66,120	2,850.00
35,000	Canadian National Ry. Co. 5s Guar.	1970	37,984.31*	40,600	1,500.00
300,000	Canadian Pacific Railway Co. Perpetual Cons. Deb. 4s	1958	264,475.00	282,000	5,547.21
100,000	Province of Alberta Deb. 4 1/8s	1958	93,750.00	83,000	2,250.00
100,000	Province of Alberta Deb. 5s	1950	101,150.00	83,000	2,500.00
150,000	Province of Manitoba Deb. 4 1/8s	1958	142,886.77	160,500	6,750.00
100,000	Province of Nova Scotia Deb. 4 1/8s	1952	100,312.50	106,000	4,500.00
250,000	Shawinigan Water and Power Co. 1st Mtg. & Coll. Tr. S. F. 4 1/8s	1967	238,310.42	262,500	11,250.00
100,000	City of Toronto Cons. Loan Deb. 5s	1949	96,164.59	111,000	5,000.00
	Income from bonds called or sold				
	Total Foreign.		\$1,389,323.05	\$1,411,520	\$59,599.85
	PUBLIC UTILITY BONDS				
\$244,000	Columbus & Southern Ohio Electric Co. Conv. Deb. 3 1/8s	1970	\$260,779.90*	\$268,400	\$7,930.00
23,900	Commonwealth Edison Co. Conv. Deb. 3 1/8s	1958	23,910.75	27,485	836.50
50,000	Consolidated Edison Co. of N. Y. Deb. 3 1/8s	1948	50,875.00	52,000	1,750.00
40,000	Consolidated Edison Co. of N. Y. Deb. 3 1/8s	1958	40,750.00	42,400	1,400.00
100,000	Detroit Edison Co. Gen & Ref. Mtg. 4s	1965	103,300.00	107,000	4,000.00

(Continued on following page)

\* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940.

**SCHEDULE OF SECURITIES—Continued**

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at date of acquisition	Market value	Interest income for year
<b>PUBLIC UTILITY BONDS—Continued</b>					
\$200,000	Gulf States Util. Co., 1st Mtg. & Ref. 3 1/8s	1969	\$213,500	\$220,000	\$7,000.00
25,000	Houston Lighting & Power Co., 1st Mtg. 3 1/8s	1966	25,750.00	26,250	875.00
200,000	Illinois Power Co., 1st Mtg. & Coll. 4 1/8s	1973	201,994.17*	206,000	866.67
87,500	Metropolitan Edison Co., 1st Mtg. 4 1/8s	1968	95,786.25	94,500	3,937.50
100,000	Minnesota Power & Light Co., 1st & Ref. Mtg. 4 1/8s	1978	92,156.25	103,000	4,500.00
50,000	Monongahela West Penn Pub. Serv. Co., 1st Mtg. 4 1/8s	1960	52,000.00	54,500	2,250.00
96,000	Montana Power Co., 1st & Ref. Mtg. 3 1/8s	1966	96,960.00	100,800	3,600.00
50,000	Northern States Power Co., 1st & Ref. Mtg. 3 1/8s	1967	47,500.00	53,500	1,750.00
100,000	Ohio Power Co., 1st Mtg. & Ref. Mtg. 3 1/8s	1968	101,500.00	108,000	3,250.00
200,000	Ohio Public Service Co., 1st Mtg. 4 1/8s	1962	102,625.00	105,000	4,000.00
200,000	Oklahoma Gas & Electric Co., 1st Mtg. 3 3/8s	1966	205,000.00	212,000	7,500.00
180,000	Oklahoma Natural Gas Co., 1st Mtg. 2 1/8s	1961	101,541.75*	101,000	1,400.00
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 3 1/8s	1961	102,500.00	108,000	3,750.00
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 4 1/8s	1964	104,000.00	107,000	4,000.00
125,000	Puget Sound Power & Light Co., 1st Mtg. 4 1/8s	1972	130,088.48*	135,000	5,312.50
147,000	Southern Natural Gas Co., 1st Mtg. Pipe Line, S. F. 3 1/8s	1956	150,410.57*	154,350	4,777.50
360,000	Texas Electric Service Co., 1st Mtg. 5s	1960	292,700.00	315,000	15,000.00
195,500	Texas Power & Light Co., 1st & Ref. Mtg. 5s	1936	200,528.02	205,275	9,775.00
120,000	Toledo Edison Co., 1st Mtg. 3 1/8s	1968	121,800.00	129,600	4,200.00
200,000	Utah Power & Light Co., 1st Mtg. 3 1/8s	1968	201,223.95*	212,000	3,479.17
263,000	Virginia Electric & Power Co., 1st & Ref. Mtg. 3 1/8s	1968	272,205.00	278,000	9,205.00
225,000	Wisconsin Electric Power Co., 1st Mtg. 3 1/8s.	1968	232,875.00	245,250	7,875.00
Income from bonds called or sold..					
\$3,541,900	Total Public Utility	...	...	\$3,624,440.06	\$188,468.38
<b>COMMUNICATION BONDS</b>					
\$280,000	American Telephone & Telegraph Co., Conv. Deb. 3s	1936	\$302,666.73*	\$344,400	\$8,400.00
51,000	American Telephone & Telegraph Co., Deb. 3 1/8s	1961	51,510.00	55,080	1,657.50
314,000	American Telephone & Telegraph Co., Deb. 3 1/8s	1966	326,706.75	339,120	10,205.00
25,000	Mountain States Telephone & Telegraph Co., Deb. 3 1/8s	1968	25,500.00	27,000	812.50
52,000	New England Telephone & Telegraph Co., 1st Mtg. 5s	1932	51,748.00	59,800	2,600.00
75,000	Southern Bell Telephone & Telegraph Co., Deb. 3 1/8s	1962	72,375.00	80,250	2,437.50
\$797,000	Total Communications.	...	\$830,506.48	\$905,650	\$26,112.50
<b>RAILROAD EQUIPMENT TRUSTS</b>					
\$82,000	Pennsylvania R. R. Co. 2 1/8s Guar.	1956	\$81,283.64	\$82,820	\$1,947.50
Income from bonds sold					
\$82,000	Total Railroad Equipment Trusts	...	\$81,283.64	\$82,820	\$2,651.50

\* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940.

**SCHEDULE OF SECURITIES—Continued**

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at Jan. 1, 1940	Market value	Interest income for year
<b>RAILROAD BONDS</b>					
100,000	Central Pacific Ry. Co., 1st Ref. Mtg. as Guar.	1949	\$48,250 00	\$52,500	\$2,000 00
100,000	Chesapeake & Ohio Ry. Co., Gen. Mtg. 4 1/8%	1992	99,464 29	140,000	4,500 00
75,000	Chicago & W. Indiana R. R. Co., Cons. 4 1/8%	1952	70,357 66	80,250	3,000 00
200,000	Eric K. Co., 1st Cons. Mtg. 5%	1995	202,572 94*	210,000	4,375 44
100,000	Great Northern Ry. Co., Gen. Mtg. 4 1/8%	1973	104,385 84	126,000	5,000 00
150,000	Louisville & Nashville R. Co., 1st & Ref. Mtg. 5%	2003	149,475 00	159,000	6,750 00
50,000	Oregon Short Line R. R. Co., Cons. 1st Mtg. 5 1/2%	1946	48,405 15	53,000	2,500 00
75,000	Pennsylvania R. R. Co., Gen. Mtg. 4 1/2%	1965	75,918 75	87,750	3,375 00
100,000	Pittsburgh, Cinc. & St. L. R. R. Co., Gen. Mtg. 5% Guar.	1960	104,662 50	124,000	4,500 00
50,000	Pittsburgh, Cinc. & St. L. R. R. Co., Gen. Mtg. 5 1/2%	1975	51,898 98	65,000	2,500 00
100,000	Southern Ry. Co., 1st Cons. Mtg. 5 1/2%	1994	103,580 34	118,000	5,000 00
67,000	Terminal R. R. Assn. of St. Louis S. F. Gen. Ref. Mtg. 4 1/2%	1953	60,878 03	75,040	2,680 00
100,000	Toledo & Ohio Central Ry. Co., Ref. & Imp. Mtg. 3 1/2% Guar.	1960	99,000 00	103,000	3,750 00
2,084,000	Union R. R. Co., Deb. 6% Guar.	1946	2,084,000 00	2,250,720	125,040 00
100,000	Virginian Ry. Co., 1st Lien & Ref. Mtg. 3 1/2%	1966	102,250 00	108,000	3,750 00
100,000	West Shore R. R. Co., 1st Mtg. 4% Guar.	2361	78,140 00	63,000	4,000 00
50,000	Western Maryland Ry. Co., 1st & Ref. Mtg. 5 1/2%	1977	42,677 19	53,000	2,750 00
Income from bonds called or sold					
<b>\$3,551,000</b>	<b>Total Railroad</b>	..	..	<b>\$3,525,916 67</b>	<b>\$3,868,260</b>
<b>INDUSTRIAL AND MISCELLANEOUS BONDS</b>					
\$100,000	Atlantic Refining Co., Deb. 3 1/2%	1953	\$102,739 31*	\$105,000	\$3,000 00
200,000	Eastern Gas and Fuel Associates, 1st Mtg. & Coll. Tr. 4%	1956	186,420 00	207,000	5,811 11
200,000	Empire Gas and Fuel Co., S. F. Deb. 3 1/2%	1962	185,687 50	204,000	7,000 00
75,000	Greyhound Corporation, S. F. Deb. 3%	1959	75,937 50	75,750	-93 75
3,000	Philipps Dodge Corp., Conv. Deb. 3 1/2%	1952	3,000 00	3,180	105 00
150,000	Phillips Petroleum Co., S. F. Deb. 4 1/2%	1964	151,466 98*	151,500	1,867 71
79,000	Railway Express Agency, Serial Notes 2 1/2% to 2 1/4%	1945-48	79,000 00	79,570	1,803 75
384,000	SHELL Union Oil Corp., Deb. 2 1/2%	1954	368,809 20	391,680	9,600 00
277,000	Socony-Vacuum Oil Co., S. F. Deb. 2 1/2%	1955	287,075 19*	290,750	7,963 75
75,000	Socony-Vacuum Oil Co., Deb. 3%	1964	78,000 00	79,500	2,250 00
200,000	Standard Oil Co., of N. J. Deb. 2 1/2%	1953	203,027 01*	208,000	5,500 00
Income from bonds called or sold					
<b>\$1,743,000</b>	<b>Total Industrial and Miscellaneous</b>	..	..	<b>\$1,721,162 67</b>	<b>\$1,791,030</b>
<b>MORTGAGES</b>					
\$100,000	Lawyers Mtg. Co., Guaranteed 1st Mtg. Cfs. 4 1/2%.	1940	\$94,422 62	**	\$725 00
80,000	Lawyers Title and Guar. Co., Guar. Mtg. Cfs. 5 1/2%.	1935	79,686 80	**	5,200 00
90,000	N. Y. Title and Mts. Co., Guaranteed 1st Mtg. Cfs. 5 1/2%.	1938	87,532 87	**	3,195 00
80,500	N. Y. Title and Mtg. Co., Guaranteed 1st Mtg. Cfs. 4 1/2%.	1948	87,530 20	**	3,710 22
<b>\$359,500</b>	<b>Total Mortgages</b>	..	..	<b>\$349,172 49</b>	<b>\$12,830 22</b>
<b>\$17,486,400</b>	<b>BONDS AND MORTGAGES—Funds Invested</b>	..	..	<b>\$17,506,926 74</b>	<b>\$694,472 68</b>

\* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940.

\*\* In liquidation, market quotations not available.

**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
	<b>PREFERRED STOCKS</b>			
100	American Brake Shoe Co., 5 1/4% Cum. Pref.	\$12,653.50	\$13,000	\$525.00
2,504	American Cyanamid Co., 5% Cum. Pref.	28,050.62	27,544	1,221.13
1,500	Appalachian Electric Power Co., 4 1/2% Cum. Pref.	159,000.00	163,500	6,750.00
1,500	Bethlehem Steel Corp., 7% Cum. Pref.	183,637.00	181,000	10,500.00
500	Case (J. I.) Co., 7% Cum. Pref.	62,225.00	74,000	3,442.83
600	Cleveland Electric Illuminating Co., \$4.50 Cum. Pref.	68,112.25	66,000	2,700.00
1,000	Deere & Company, 7% Cum. Pref.	28,812.50	35,000	1,400.00
1,125	duPont (E. I.) de Noveours & Co., \$4.50 Cum. Pref.	116,125.00	141,750	5,062.52
1,500	General Motors Corp., \$5.00 Cum. Pref.	187,937.50	192,000	7,500.00
1,300	GoodYear Tire & Rubber Co., \$5.00 Cum. Pref.	129,867.50	135,200	4,875.00
700	GoodYear Tire & Rubber Co., \$5.00 Cum. Conv. Pref.	73,195.00	77,700	2,625.00
225	Kress (N. Y. T.) Co., 5 1/2% Cum. Sol. Conv. Pref.	7,642.76	5,400	225.00
5,000	Kress (N. H.) Co., 6% Cum. Sol. Pref.	58,260.00	55,000	3,000.00
1,500	McKesson & Robbins Inc., \$4.00 Cum. Pref.	144,000.00	155,600	6,000.00
1,000	New York State Electric & Gas Corp., 5.10% Cum. Pref.	103,250.00	109,000	5,100.00
1,000	Northern States Power Co., 5% Cum. Pref.	103,000.00	112,000	5,000.00
550	Ohio Power Co., 4 1/2% Cum. Pref.	59,925.00	62,700	2,475.00
1,500	Pacific Telephone and Telegraph Co., 6% Cum. Pref.	235,220.75	237,000	9,000.00
600	Public Service Co. of Oklahoma, 5 1/2% Cum. Pref.	60,900.00	66,000	3,000.00
1,134	Sherwin-Williams Co., 5 1/2% Cum. Conv. Pref.	124,985.75	128,142	5,670.00
1,250	Standard Oil Co. of Ohio, 4 1/2% Cum. Conv. Pref.	133,472.50	140,000	5,784.37
1,000	Standard Oil Co. of Ohio, 5% Cum. Pref.	169,385.47	111,000	5,000.00
2,000	United Gas Corp., \$7.00 Cum. Pref.	236,950.00	232,000	21,000.00
1,500	U. S. Rubber Co., 8% Non Cum. 1st Pref.	184,337.50	223,500	9,800.00
3,100	U. S. Steel Corp., 7% Cum. Pref.	443,407.57	412,300	21,500.00
	Income from stocks converted or called			3,405.00
33,688	Total Preferred Stocks		\$3,163.236	\$150,960.85
1,800	Air Reduction Company	\$107,905.16	\$70,200	\$3,600.00
2,000	American Brake Shoe Co.	87,580.95	88,000	3,800.00
2,600	American Can Company	230,767.37	226,200	6,450.00
4,600	American Cyanamid Co.	143,267.98	161,000	4,764.36
4,000	American Radiator & Standard Sanitary Corp.	73,154.91	48,000	1,600.00
700	American Telephone & Telegraph Co.	100,793.00	114,800	3,825.00
	Armstrong Cork Company	11,794.24	17,600	.....
				381,283.64

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**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
				COMMON STOCKS—Continued
1,600	Boston Edison Company	\$58,267	61	\$57,600
2,600	Caterpillar Tractor Co.	175,811	00	\$5,200
4,200	Chase National Bank of N. Y. . .	142,667	50	4,620
4,000	Chrysler Corporation	135,973	04	10,050
1,000	Cleveland Electric Illuminating Company	366,000	00	112,50
700	Coca-Cola Company	36,336	63	375
1,500	Cobratec-Pioneer-Peet Company	91,695	00	200
3,100	Commercial Investment Trust Corp.	43,533	12	45,000
2,700	Commercial National Bank and Trust Co. of N. Y.	160,378	15	138,500
2,100	Commonwealth Edison Company	116,805	00	120,600
4,600	Continental Can Co.	58,733	36	66,900
1,500	Continental Illinois National Bank & Trust Co. of Chicago	183,800	16	179,400
2,908	Continental Insurance Co.	128,350	00	147,000
6,000	Continental Oil Co. of Delaware	109,416	78	139,584
1,500	Delaware Power & Light Company	162,943	08	168,000
1,180	Dow Chemical Co.	23,897	78	24,000
2,800	duPont (E. I.) de Nemours & Co.	142,892	28	144,500
2,500	Eastman Kodak Co.	433,335	85	438,000
100	First National Bank of N. Y.	401,693	75	422,500
700	Food Machinery Corporation	152,840	00	168,500
10,900	General Electric Co.	42,743	89	42,000
6,100	General Foods Corporation	426,469	09	414,200
8,800	General Motors Corporation	251,321	45	250,100
2,900	Goodrich (B. F.) Co.	451,730	90	536,800
3,000	Goodyear Tire & Rubber Co.	122,833	10	142,100
5,800	Grant (W. T.) Co.	117,429	40	141,000
650	Guaranty Trust Co. of N. Y.	195,921	10	220,400
7,100	Gulf Oil Corp.	176,951	50	208,000
1,900	Hartford Fire Insurance Co.	284,515	31	326,600
8,600	Humble Oil & Refining Co.	164,034	68	188,100
2,200	Insurance Company of North America	257,024	26	344,000
1,300	International Business Machines Corp.	160,334	83	195,800
800	International Nickel Company of Canada, Ltd.	179,172	19	226,269
1,100	Johns-Manville Corp.	24,498	34	24,000
1,000	Kennecott Copper Corporation	106,292	15	105,600
5,000	Kresge (S. S.) Company	35,292	15	34,600
662	Lawyers Mortgage Corp., Voting Trust Ctf.	114,950	90	130,000
1,900	Liggett & Myers Tobacco Co., "B"	171,301	08	1,936
1,500	Liquid Carbonic Corporation	39,435	40	40,500

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(Continued on following page)

**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
<b>COMMON STOCKS—Continued</b>				
3,400	Merck & Co., Inc. ....	\$138,770.99	\$112,200	\$3,400.00
2,300	Minneapolis-Honeywell Regulator Co. ....	90,360.12	96,600	850.00
3,000	Monsanto Chemical Co. ....	255,000	5,225.00	
6,700	Montgomery Ward & Co. ....	320,937.72	348,400	13,000.00
6,400	National Cash Register Co. ....	183,931.77	211,200	5,025.00
1,000	National City Bank of New York ....	38,025.00	37,000	
1,960	National Fire Insurance Co. of Hartford ....	112,467.50	113,680	3,570.00
3,300	Newberry (J. J.) Co. ....	170,342.00	217,800	6,420.00
3,500	New Jersey Zinc Co. ....	224,223.73	231,000	9,000.00
3,200	Owens-Illinois Glass Co. ....	197,239.00	185,600	6,400.00
2,900	Penney (U. C.) Co. ....	264,135.69	307,400	14,500.00
700	Pepsi-Cola Company ....	43,144.88	43,400	100.00
3,800	Phillips Petroleum Co. ....	141,339.08	132,000	4,400.00
1,600	Pittsburgh Plate Glass Co. ....	175,766.75	187,200	5,250.00
3,800	Procter & Gamble Co. ....	212,774.43	216,600	6,250.00
2,000	Scott Paper Co. ....	82,542.73	88,000	3,420.00
4,000	Sears, Roebuck & Co. ....	313,183.92	392,000	16,175.00
6,600	Sharp & Domine, Inc. ....	93,080.03	85,800	2,800.00
1,700	Sherwin-Williams Co. ....	165,661.97	173,400	4,800.00
13,800	Soccony-Vacuum Oil Co. ....	168,875.81	165,600	6,875.00
2,100	Squibb (E. R.) & Sons ....	123,905.00	117,600	3,900.00
1,600	Standard Brands Incorporated ....	48,132.02	44,800	200.00
6,900	Standard Oil Co. of Indiana ....	205,372.92	227,700	10,000.00
4,800	Standard Oil Co. of New Jersey ....	248,503.38	264,000	9,625.00
2,300	Texas Company ....	96,823.98	108,100	4,600.00
4,100	Timken Roller Bearing Co. ....	196,850.70	209,100	6,450.00
3,800	Union Carbide & Carbon Corp. ....	321,083.50	304,000	11,400.00
60	Union Trust Company of Pittsburgh ....	97,150.18	103,500	1,050.00
3,300	United Fruit Company ....	244,970.61	290,400	9,325.00
2,700	United States Gypsum Co. ....	231,440.23	205,200	3,700.00
3,300	Westinghouse Electric & Mfg. Co. ....	346,049.63	346,500	13,200.00
3,200	Woolworth (F. W.) Co. ....	123,319.54	131,600	3,800.00
	Income from stocks sold ....	.....	.....	11,642.50
247,620.40	Total Common Stocks ....	.....	\$13,448,019	\$442,438.36
281,308.40	COMMON AND PREFERRED STOCKS—Funds Invested	.....	\$15,818,116.54	\$16,611,255
	AGGREGATE INVESTMENTS (BONDS AND STOCKS) ....	.....	\$33,325,043.28	\$34,554,859*

\* Represents total interest and dividend income for year before deduction of amortization of bond premiums.

REPORT OF THE PRESIDENT  
OF THE  
CARNEGIE INSTITUTION OF WASHINGTON  
FOR THE YEAR ENDING OCTOBER 31, 1944



REPORT OF THE PRESIDENT  
OF THE  
CARNEGIE INSTITUTION OF WASHINGTON

The By-Laws of the Institution provide for an annual report by the President, in order that the Trustees may be better enabled to judge of its progress and determine its policies. This report will, like the reports of the past few years, present very little regarding results of research, for most of these have been confidentially reported to the Government and will appear only gradually and under control. There is much to be considered, however, in regard to programs and policies; for the Institution will soon, it is to be hoped, return to its normal paths of public research for the common good; and the transition from war to peace will present many problems.

The staff is eager to relinquish its war duties and to return to more fundamental and satisfying research. The President, for one, looks forward with enthusiasm to the time when his full effort can be devoted to the Institution and when he can join his colleagues in planning for its future accomplishments. There will be a reaction among the staff when the war ends, just as there will in the entire country; men will be weary, and it will not be too easy to turn from the hectic pace of war research to the orderly deliberation that is more effective for the advancement of knowledge in intricate fields. The thing to do, evidently, is to obtain such interval of respite as will be necessary for readjustment and relaxation, and then to start together and deliberately a long pull toward distant but important objectives.

If we have learned anything whatever out of recent experience, military research will continue after the end of the war on a more extensive basis than was the case between wars. It will be a part of a general effort not to relax completely into lethargy regarding our own protection. We have twice been fortunate, as allies have held off aggressors while we prepared, and we are not, I trust, likely to be caught as seriously unprepared again. There is a conviction that we must participate actively in definite efforts to maintain the peace, and at the same time keep our powder dry, but it remains to be seen how far this realistic attitude can this time be maintained. There will again be the tendency to rationalize our views of history in such a manner as to justify easy ways. There will once more be idealists who will mistake desire for accomplishment. Unfortunately there will always be those persuasive ones who will imply that grappling with the hard facts of life is for lesser minds, and that war can be avoided by abolishing the thought of it locally rather than universally. Ours will be an exceedingly attractive country to build and fashion, and the temptation to forget will be great. Yet two wars in a generation must have made their imprint, and there will be a continuing demand that we do not lapse entirely into self-imposed provincial ignorance of world trends and their potential effect upon our way of life. The world has the best opportunity possible for a long peace, if we really remain strong and do our

## CARNEGIE INSTITUTION OF WASHINGTON

part. An essential ingredient is continuing attention to the possible military applications of expanding science. These we must know, and the provisions for ensuring that we do, in the years before us, are of great importance to the welfare of this country.

Yet military science is science of the most blatantly applied type, and the Institution has been devoted throughout its existence to basic science at the opposite extreme. There was probably no organization in the country that had to make a more radical adjustment of its methods of thought in order to participate effectively in the conduct of war. The fact that it has done so by no means indicates that it has altered its philosophy; it has merely

departed from its customary modes of operation for a time under necessity, and is anxious to return. In normal times it would not be expected that the Institution would be inclined to participate directly in military research; such research can be done more appropriately and hence better and with less disruption by organizations whose work is closer to definite application. Individuals in the Institution will undoubtedly continue their interest and influence in many cases and will participate in scientific advisory activities and the like. Soon, however, the Institution as such will be able to terminate its military research with a clear conscience and return to normal ways.

### PLANS FOR THE FUTURE

When this occurs the Institution will have a rare opportunity to make a fresh start. It is well, in the affairs of any organization, to pause at times to take account of stock and redefine aims. The pause in this instance is imposed upon us, but it can be seized upon and taken advantage of. Much of our planning must nevertheless wait, for the very good reason that we wish members of our staff now absent to participate in the planning, and also because we wish to approach at least the tougher parts when reasonably refreshed. This report of the President, therefore, in which as always the attempt is made to interpret and place before the Trustees the group aspirations and opinions of the staff, will comment upon a number of matters that seem to be involved in preparing for a new start, but will not attempt to place many of them in form for definite action through adoption of policies or otherwise. Most of these matters require more thought than we have yet had time to give them.

In approaching the future we need not be slaves to the past. True, our programs must fit our facilities and the qualifications of our staff, but we do not need to follow a path merely because we have followed it a long time. We should follow it only if re-examination shows that the path is good and leads to a genuinely worthwhile goal.

The most important element of our planning is the definition of the programs of the several departments. These should never be so rigid as to exclude the seizure of unexpected opportunities, but neither should they be left floating in the air. We should be willing courageously to attempt to state what it is that we wish to find out as a result of our research efforts and why we wish to know it. It will take courage also to eliminate growths that do not contribute to the main stem, or have their own worth-while objectives. Programs of research groups are usually constructed, in the last analysis, by the groups themselves; for there is nothing

more true than that it is impossible to conduct research on more than a mediocre plane unless the objectives reflect the aspirations of those who are to achieve them. The Institution needs men of diverse talents and even of diverse caliber, for modern research is usually an affair of well constituted teams, but we cannot tolerate mediocrity in our objectives or our ultimate accomplishments. The initiative toward the formation of programs should come from the staffs of the several departments, guided and correlated in their studies by their directors. These will need review, for the plans of any group of enthusiasts will always need evaluation by those who view the situation more generally and with detachment, and they will be better plans if they are convincingly prepared. In due time it will be the pleasant duty of the President to consult with members and directors during their deliberations and to interpret plans to the Trustees as their potential values are weighed.

An adequate approach to the formulation of long-range programs of research in the several departments can be made only if there is a clear grasp of the aims of the Institution as a whole. Its object, as recited in the Articles of Incorporation, is "to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Before a program can be constructed with assurance it is necessary to be somewhat more explicit. New knowledge can be of value because its application enables man to cope more adequately with his environment, to provide shelter, food, and clothing on a more satisfactory scale and to greater numbers, to enrich lives by improvements in communication and trans-

portation, or to maintain well-being by a more successful struggle with disease. When the object is thus clear, the formulation is relatively straightforward, and the natural function of the Institution is to lay the groundwork by fundamental research as a basis for further advance. New knowledge, however, may also be of value to mankind by the enrichment of intellectual life, the extension of the boundaries of vision, and the more complete appreciation of the extraordinary setting in which the spark of intellect flares up for its brief adventure in living. Such an objective is certainly no less worthy than one that is more concrete, but its pursuit is more subtle. No one can tell completely in advance what may follow upon the addition of the least increment to the sum total of human knowledge. Still, it is possible to have some standards, and some estimation of relative importance. A research result which will be known and appreciated by only a handful of specialists may be of great importance if it extends their efforts substantially toward a common goal. A research result which becomes known to millions may indeed be trivial in its effect on the progress of sound science. Yet there is a great body of investigative work which is aimed at broadening and deepening the cultural pattern of the people, and it seems only reasonable that such effort should be accompanied by at least some conception as to how this cultural enrichment is to be accomplished, beyond the mere act of placing the result of the research in the scientific record. The Institution, because of the broad nature of its work, has an opportunity for interpretation and dissemination. In some fields this seems to be an essential part of a rounded effort, and it is not altogether satisfactory to have it done entirely by

## CARNEGIE INSTITUTION OF WASHINGTON

others. It appears that reasonable and dignified provision for such efforts might well appear in our plans.

The next most important task, as we face a promising future, is to make sure our internal policies and our external relations are in sound condition for the task in hand. We have a set of policies and a considerable amount of tradition as our guide, but in a number of aspects they warrant re-examination. Whether we need to arrive at a set of explicit written policies, governing all phases of relationship with one another and with our neighbors, is questionable. The British seem to get on quite as well with an unwritten constitution as we do with a written one. But certainly we need to explore some of these subjects carefully until we arrive at the point of clear-cut policy which all understand.

Progress has been made on several matters. A considerable amount of discussion has occurred regarding policy on patents, where there are some loose ends to be tucked in. More discussion has occurred on matters of external relations in connection with the publishing of books, the giving of lectures, and the rendering of scientific advice to industry. This last point has its difficulties. Certainly, if there are results emerging from our basic research programs which can be used by industry to increase the standard of living or improve the public health, we have an obligation to see that we are not so entirely insulated from such applications that opportunities are lost. Relations between industrial research laboratories and our own can in fact be mutually beneficial. It is just as sure, however, that if we were to allow individual industrial units to secure privately the results of some of our research, with failure to recognize that our funds should not be expended for the

commercial benefit of alert industrial organizations, the result would not only be inequitable, it would be destructive of internal morale. There is no problem in the way in which our scientific group mingles with scientists generally, and there are only very minor problems in our relations with universities. Our research is so fundamental and basic that there are no problems in connection with our relations with industry which cannot readily be surmounted. Such as there are, however, require more attention than they have as yet received. These matters, and some others, have been placed before the Executive Committee and the Trustees from time to time. When our absent staff members return it should be possible to bring them to a focus.

One subject, however, is of such definite and immediate importance as to require prompt consideration. This concerns the revision of our retirement plan. As a result of lower interest rates and of increased life expectancy, the prospective annuity for a young man starting contributions at present under our existing plan is little more than half the amount he could have counted upon had he started twenty-five years ago. This situation has required thorough restudy of the Institution's position with respect to cooperation in provision for retirement income, and this study has resulted in recommendations for modification and restatement of annuity procedure for consideration by the Executive Committee. It is hoped that new and appropriate regulations may become effective by the first of next year.

Another matter that warrants further attention at the proper time is the entire subject of staff grades and tenure. This is closely allied with a second subject, which is perhaps of greater importance, and which warrants a section by itself.

## REPORT OF THE PRESIDENT, 1944

### YOUNG SCIENTISTS

It is axiomatic that the ultimate accomplishments of the Institution depend upon a steady influx into its ranks of brilliant young men. Yet there seems to have been no definite and accepted procedure for bringing this about. Unlike a university, the Institution does not have a succession of graduate students passing through, from which it can select some of the most scholarly and promising individuals for a period of trial in its teaching ranks. Neither does it have a revolving group of fellows pursuing post-doctorate research. Its system of recruiting has been somewhat haphazard. Yet it is essential that in some manner this process of finding

and selecting young men of great promise be placed on an effective basis, for the ultimate investment of the Institution in the unique opportunity that is furnished each individual who follows a full research career in its service is very large. It is also true that senior research men often need the impact of young minds for continued stimulation. The process by which this can best be accomplished will undoubtedly differ from one department to another. It should be carefully worked out. At the same time, of course, we should not lose the benefits which have long followed the practice of establishing useful relations with mature scientists in other organizations.

### CARNEGIE CORPORATION OF NEW YORK

This is a fitting time to review briefly the constantly sympathetic and helpful consideration with which the Carnegie Corporation has watched the growth and progress of Institution activities.

In 1925 the Trustees of the Corporation authorized an appropriation of \$5,000,000, which was paid to the Institution with interest over a period of five years as an increase in its endowment. At the same time the Trustees of the Corporation voted to give sympathetic consideration at the proper time to the Institution's request for a further grant of \$5,000,000 for endowment. This request was honored at a meeting of the Corporation on January 20, 1944, and an additional sum of \$5,000,000 was paid to the Institution on September 20, 1944.

The Corporation has increased the Endowment Fund of the Institution by 45 per cent. It has provided over \$2,000,000 for current support of the Institution's work, three-quarters of this amount being in the nature of emergency aid needed because of economic conditions brought about by the first World War, and for cooperation with other agencies in the extension of research programs of a terminating nature. The Corporation, furthermore, has given liberally for direct support of specific research projects conducted by the Institution and for miscellaneous research projects that have been supervised by the Institution at the request of the Corporation. The following tabulation summarizes the situation:

\$10,000,000	Endowment Fund
600,381	Interest on endowment (during period of payment) used for support of current work
1,500,000	Emergency support
644,000	Support of special projects conducted by Institution
939,861	Grants for research projects supervised by Institution at request of Corporation
<hr/> <b>\$13,684,242</b>	

## CARNEGIE INSTITUTION OF WASHINGTON

The generous action of the Carnegie Corporation permits a freedom of prospect and opportunity which is matched by the sense of responsibility for employing the

resulting increase in income in the most effective manner for the advance of basic research and for pioneering in specific fields.

### FINANCES

When the war is over, if we assume that there will be no general inflation in the United States, the Institution will be in good financial condition. In the first place, the addition by the Carnegie Corporation of New York of \$5,000,000 to our endowment gives us new money which is not committed and will be generally available. Secondly, our experience during the war has been rather extraordinary. We entered the war effort with the policy that the Institution would render aid to Government by contributing the use of its facilities, the services of its existing scientific staff, and its normal overhead costs. We therefore contracted, in connection with war research, for Government funds only sufficient to meet added out-of-pocket expenses due to new assistants, materials, and increased and extraordinary costs of various sorts. Under this policy, although some extra expense has necessarily oc-

curred which could not be thus reimbursed to us, this has been more than offset by budget relief arising from the fact that many of our staff have gone on leave of absence without salary to enter Government service elsewhere. Part of our normal expenditures, as budgeted, therefore remains in our hands; and such funds have been set aside and placed in reserves. They will be available to meet extra costs of reconversion of the Institution to its normal affairs and will undoubtedly be fully absorbed in this process, thus leaving our reserves much as they were when the war started. Thus it appears that we shall emerge from the war, having devoted a large part of our effort to war research without reimbursement, but without having crippled the Institution financially as it faces the future, which is a fully desirable situation.

### PARTICIPATION IN WAR ACTIVITIES

All divisions and departments of research of the Institution are still actively engaged, through contractual relations with the Government or by participation of individual staff members, in carrying on investigations directly related to the war effort. Government contracts have been entered into for thirty-two projects, work upon eighteen of which has been completed. These projects are covered by ninety-two contracts, orders, or amendments, by means of which \$3,638,120 has been made available for reimbursement to

the Institution for out-of-pocket expenses.

Of the fourteen active projects, eight are sponsored by the Office of Scientific Research and Development, the others having been undertaken at the request of the War Department, the Navy Department, the War Production Board, and the National Institute of Health. Forty-seven members of the Institution are on leave of absence to serve the Government through other channels, and about 75 per cent of the entire staff of the Institution is now directly concerned with war activities.

## REPORT OF THE PRESIDENT, 1944

### WALTER A. JESSUP

Walter A. Jessup died on July 5, 1944, in his sixty-sixth year. He became a Trustee of the Carnegie Institution of Washington in December 1938, and was immediately elected to fill a vacancy in its Executive Committee. He brought to his colleagues on the Board a broad experience in the field of American education, and a liberal and practical conception of educational procedure. As an Executive Committee member he has contributed directly to a sound and sympathetic approach to problems dealing with research personnel, organization of research groups, and relations of the Institution with other research and educational agencies.

Dr. Jessup became President of the Carnegie Foundation for the Advancement of Teaching in 1934, and he succeeded Dr. Keppel as President of the Carnegie Corporation in 1941. His membership in the Board of Trustees of the Institution has tended to strengthen the cordial relations already established between various Carnegie benefactions, and to accentuate the over-all purpose of the Founder in providing means for the advancement and application of knowledge and the improvement of cultural relations.

The Institution has lost an enthusiastic friend and a counselor of integrity, vision, and sound judgment. We shall miss him exceedingly as we plan for the future.



# REPORTS OF DEPARTMENTAL ACTIVITIES AND COOPERATIVE STUDIES

## ASTRONOMY

*Mount Wilson Observatory*  
*Special Projects*

## TERRESTRIAL SCIENCES

*Geophysical Laboratory*  
*Department of Terrestrial Magnetism*  
*Special Projects*

## BIOLOGICAL SCIENCES

*Division of Plant Biology*  
*Department of Embryology*  
*Department of Genetics*  
*Nutrition Laboratory*  
*Special Projects*

also:

F

## HISTORICAL RESEARCH

*Division of Historical Research*  
*Special Projects*



# MOUNT WILSON OBSERVATORY

*Pasadena, California*

WALTER S. ADAMS, *Director*

With the temporary absence of two additional members of the scientific staff to study problems connected with the war, and with the increasing absorption of the remaining members in similar activities, the astronomical work of the Observatory has necessarily been somewhat reduced. The most essential observations, however, and those the value of which would be most seriously impaired by a lack of continuity have been maintained with as slight interruption as possible.

One of the heaviest snowstorms in the history of the Observatory occurred in February 1944, nearly 60 inches falling within three days. No serious damage was done to the buildings, but the main highway to Mount Wilson was blocked for a period of two and one-half months, and repairs upon the power-transmission line could not be completed by the Southern California Edison Company for nearly seven weeks. During this time few observations could be made, but since the weather was in general unfavorable the loss was not

great. The Toll Road used for transportation from Pasadena in previous years was temporarily reopened by the County Road Department pending repairs to the main highway.

Perhaps the most interesting observational result of the year has been the resolution into stars of several extragalactic nebulae, among them the two companions of the Andromeda nebula and the central region of the Andromeda nebula itself. Red-sensitive photographic plates were used with a filter transmitting a very limited spectral region, the minimum exposure times being about four hours. These observations were extremely exacting, requiring excellent seeing, little temperature change of the telescope, accurate guiding, and a dark transparent sky. The "black-out" of the San Gabriel Valley during the period of the observations was at least partly responsible for their success. Many conclusions of interest can be drawn from these remarkable photographs with their excellent definition.

## STAFF AND ORGANIZATION

### RESEARCH DIVISION

*Solar Physics:* Seth B. Nicholson, Harold D. Babcock, Joseph Hickox, Edison Hoge, Edison Pettit, Robert S. Richardson, Mary F. Coffeen, Elizabeth S. Mulders, Myrtle L. Richmond.

*Stellar Motions and Statistics:* Adriaan van Maanen, Ralph E. Wilson,\* A. Louise Lowen.

*Stellar Photometry:* Walter Baade, Mary Joyner Seares.

*Stellar Spectroscopy:* Walter S. Adams, William H. Christie,\* Theodore Dunham, Jr.,\* Milton L. Humason, Alfred H. Joy, Paul

W. Merrill, Rudolph Minkowski, Roscoe F. Sanford, Gustaf Strömberg,\* Olin C. Wilson,\* Ralph E. Wilson,\* Ada M. Brayton, Dorothy D. Locanthi,\* Sylvia Burd, Cora G. Burwell, A. Louise Lowen.

*Nebular Photography, Photometry, and Spectroscopy:* Edwin P. Hubble,\* Walter Baade, Milton L. Humason, Rudolph Minkowski, Sylvia Burd.

*Physical Laboratory:* John A. Anderson, Robert B. King.\*

*Editorial Division:* Paul W. Merrill, editor;

\* On leave of absence for investigations relating to the war.

Elizabeth Connor, assistant editor and librarian; Alice S. Beach, secretary and stenographer.

Alfred H. Joy has continued throughout the year as Secretary of the Observatory.

Nearly all the members of the staff who remain in Pasadena have been actively engaged in work upon contracts of the Observatory with the military forces and the Office of Scientific Research and Development.

Dr. John A. Anderson, physicist and a member of the Observatory staff since 1916, retired on September 1, 1943. His scientific contributions and the important part he has had in the design and construction of the 200-inch telescope have taken a noteworthy place in the history of the Observatory.

#### RESEARCH ASSOCIATES

Sir James Jeans, Dorking, England; Henry Norris Russell, Princeton University; Frederick H. Seares, Pasadena; Joel Stebbins, University of Wisconsin.

Dr. Russell, although unable to visit the Observatory during the present year, has been actively engaged in the term analysis of the spectra of rare earths, utilizing observational material provided by Dr. A. S. King. Dr. Seares with the assistance of Miss Joyner has completed four important photometric investigations dealing with the colors and magnitudes of the north polar stars, the relation of color index to effective wave length, and space absorption in the Pleiades cluster. Dr. Stebbins spent the summer months of 1943 in Pasadena and continued his measurements of a selected list of stars of various spectral types with his photoelectric photometer.

#### TEMPORARY ASSOCIATES

Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, carried

on observations of the radial velocities of faint stars with the instruments on Mount Wilson during a period of about five weeks in August and September 1943. Dr. John C. Duncan, Director of the Whittier Observatory, used the 60-inch and 100-inch telescopes during the summer months to photograph several nebulae of interest, and returned to Pasadena in May 1944 for further work. Dr. Duncan also aided in the observations carried on by Babcock at the Solar Laboratory. Dr. P. Swings, who is engaged in war work in Pasadena, has been a frequent visitor to the Observatory during the year and has completed some interesting investigations on rare earths in stellar spectra.

Miss Suzanne van Dijke, Fanny Workman Fellow at Wellesley College, spent the months of March and April 1944 at the Observatory in a study of high-dispersion spectra of giant and dwarf stars.

#### INSTRUMENT DESIGN AND CONSTRUCTION

*Design:* Edgar C. Nichols, chief designer; Harold S. Kinney, designer.

*Optical Shop:* Donald O. Hendrix, superintendent.

*Instrument Shop:* Albert McIntire, foreman; Elmer Prall, instrument maker; Myo C. Hurlbut, Fred Scherff, Oscar Swanson, Albert Labrow, Donald Yeager, machinists; James Chapman, pattern maker; Harry S. Fehr, cabinet maker.

#### MAINTENANCE AND OPERATION

*Office:* Anne McConnell, bookkeeper; Dorothy Neuens, stenographer and telephone operator.

*Operation:* Ashel N. Beebe, superintendent of construction; Sidney A. Jones (on leave of absence for military service) and Kenneth de Huff, engineers; Thomas A. Nelson, Floyd Day, Louis S. Graf, night assistants; Ernest W. Hartong, truck driver and machinist helper; Anthony Wausnock, Mrs. Wausnock, and Mrs. Pauline Byers, stewards; Arnold T. Ratzlaff, Irving Angel, and Harry Sering, janitors.

Several of those whose names are listed above have been with the Observatory but a part of the year.

Numerous additions have been made

to the staffs of the optical and instrument shops in connection with the Government contracts which have been undertaken by the Observatory.

### OBSERVING CONDITIONS

As already indicated, the winter of 1943-1944 was characterized by exceptionally heavy snowfall, amounting to 99 inches for the season. No serious damage to buildings or instruments occurred. The total precipitation was 42.5 inches, about four inches above the normal. The autumn months of 1943 were favorable for observations, but the stormy conditions later in the winter and the interruption in February, March, and April 1944, due to the breaking of the power-transmission line, reduced the amount of actual observing time to considerably below the average. The accompanying table shows the distribution by months of observations with the 60-inch telescope.

MONTH	OBSERVATIONS		
	All night	Part of night	None
<b>1943.</b>			
July	25	5	1
August	25	5	1
September	26	4	0
October	18	5	8
November	17	10	3
December	7	9	15
<b>1944.</b>			
January	7	9	15
February	1	11	17
March	0	0	31
April	3	10	17
May	18	6	7
June	14	4	12
Total	161	78	127
Mean 32 years	205	84	76

### SOLAR RESEARCH

#### SOLAR PHOTOGRAPHY

Solar photographs were made on 266\* days between July 1, 1943 and June 30, 1944 by Hickox, Hoge, Nicholson, and Richardson, as follows:

Direct photographs	532 *
<i>Ha</i> spectroheliograms of spot groups,	
60-foot focus	524 *
<i>Ha</i> spectroheliograms, 18-foot focus	1080 *
K2 spectroheliograms, 7-foot focus	4373 *
K2 spectroheliograms, 18-foot focus	1036 *
K prominences, 18-foot focus	996

\* Between February 19 and April 6, inclusive, the 60-foot tower telescope could not be used because of the interruption to the electric power supply.

#### SUNSPOT ACTIVITY

Nicholson and Mrs. Mulders have continued their regular study of sunspots.

During the calendar year 1943, sunspot activity decreased normally. Observations were made on 323 days; 46 days were without spots, as compared with 16 in 1942. Six groups of the new cycle, all in the southern hemisphere, were observed in 1943. In the waning cycle, the number of groups decreased from 188 in 1942 to 89 in 1943; the number in the northern hemisphere decreased from 93 to 54; in the southern hemisphere, from 95 to 35.

Until the new cycle is further developed, the exact date of the minimum cannot be determined, but it will probably be about the middle of the year 1944.

The monthly means of the number of groups observed daily during the past two and one-half years are given in the following table.

MONTH	DAILY NUMBER		
	1942	1943	1944
January . . . . .	3.3	1.1	0.3
February . . . . .	4.4	2.0	0.1
March . . . . .	4.9	2.4	1.1
April . . . . .	5.2	2.1	0.1
May . . . . .	2.6	1.8	0.2
June . . . . .	1.3	1.7	0.7
July . . . . .	1.9	1.3	.
August . . . . .	2.1	2.2	.
September . . . . .	2.1	0.9	.
October . . . . .	2.4	0.8	.
November . . . . .	3.0	1.3	.
December . . . . .	2.6	1.5	.
Yearly average	3.0	1.6	.

#### SUNSPOT POLARITIES

Magnetic polarities in each spot group have, so far as possible, been observed at least once. The classification of groups observed between July 1, 1943 and June 30, 1944 is indicated in the table given below. "Regular" groups of the old cycle in the northern hemisphere are those in which the preceding spot has N (north-seeking) polarity and the following spot S polarity; in the southern hemisphere the polarities are reversed. For spot groups of the new cycle, the distribution of magnetic polarities is opposite to that just described for the old cycle.

Hickox. An eruptive prominence photographed with the 13-foot spectroheliograph by Hickox on April 18, 1944 appeared within a few months of the expected sunspot minimum. This is the fourth minimum at which eruptive prominences have been observed (one each) since the earliest catalogue entry in 1885. There are now 67 entries. Of these, 77 per cent have been observed in the interval from maximum to minimum. The prominence of April 18 rose to the greatest height (600,000 km) of any observed at minimum.

The trajectories of eruptive prominences for which photographic evidence is available now number 40. Most of these are nearly rectilinear, the principal deviations occurring at the beginning and less frequently at the end of the eruption.

The apparent inclination,  $I$ , of the trajectories has varied from  $0^\circ$  to  $63^\circ$ . From the theory of random distribution the frequency of various values of  $I$  can be determined. Such a comparison by Pettit shows that there are more eruptions with trajectories of small inclination than a random distribution would indicate.

#### ULTRAVIOLET SPECTRUM OF THE SUN

Observing conditions at the Hale Laboratory have been subnormal, on the average, but at times it has been possible for

HEMISPHERE	POLARITY					
	REGULAR		IRREGULAR		UNCLASSIFIED	
	Old cycle	New cycle	Old cycle	New cycle	Old cycle	New cycle
North . . . . .	19	0	2	0	5	1
South . . . . .	10	9	1	0	9	1
Whole sun . . . . .	29	9	3	0	14	2

#### PROMINENCES

Observations of solar prominences have been made by Nicholson, Pettit, and

Babcock to obtain excellent ultraviolet spectrograms, which provide, for the first time, a normal background extending to

$\lambda 2975$ . The scale of wave lengths near  $\lambda 3000$  has been connected with the International scale at  $\lambda 4500$  by means of overlapping orders of spectra, and the positions of about 1000 lines have been determined between  $\lambda 2949$  and  $\lambda 3153$ . The spectrum of the center of the disk has been compared with that for points ranging from 0.75 to 0.96 of the solar radius. Suppression of the wings of strong lines, a phenomenon familiar near the limb in the visible region, can here be traced farther toward the center. Some notable variations appear among weak lines as well.

#### GENERAL MAGNETIC FIELD AND SOLAR ROTATION

Two series of spectrograms have been obtained near  $\lambda 5300$  with the Lummer plate and special polarizer at solar latitudes  $\pm 45^\circ$  for a study of the general magnetic field of the sun. The Lummer plate has also been used for a few additional observations of rotational velocity at points between 0.77 and 0.87 of the solar radius.

#### THE H AND K LINES AND MAGNETIC STORMS

Reference was made in last year's report to the comparison of photographs of the H and K lines taken by Richardson during the violent magnetic storms of September 18, 1941 and March 1, 1942 with similar photographs taken during a period of magnetic calm. The object was to test the suggestion by Chapman that a cloud of charged particles moving earthward during a magnetic storm might be detected by a faint absorption line on the violet side of the solar lines.

Reduction of the plates reveals what appears to be a very shallow absorption band beginning near the center of H and K and extending about 12 Å to the violet with a maximum depth of slightly less than 1 per cent. For the storm of September 18, 1941 the apparent absorption corresponds to a maximum velocity of 1100 km/sec and a mean velocity of 680 km/sec; for the storm of March 1, 1942 the maximum velocity is 1000 km/sec and the mean velocity 550 km/sec.

### STELLAR INVESTIGATIONS

#### PARALLAXES AND PROPER MOTIONS

The parallaxes of 28 stars of large proper motion observed and measured by van Maanen are included in a list now in press. Seven of the stars are found to have absolute magnitudes fainter than +15.0, one being +19.2 or nearly 15 magnitudes fainter than the sun in intrinsic brightness. Nearly all the stars in the list for which spectra have been determined are M-type dwarfs.

The extensive investigation by van Maanen of the  $\eta$  Persei cluster has been completed and prepared for publication. Approximately 800 stars ranging down to magnitude 16.1 were measured on two

pairs of photographs separated by intervals of 17 and 29 years, respectively. The proper motions indicate that about 700 of the stars belong to the cluster and about 100 are field stars and not members of the cluster. The final values of the annual proper motion derived from groups of stars of all magnitudes are  $+0.^{\circ}0016 \pm 0.^{\circ}0005$  in right ascension, and  $-0.^{\circ}0033 \pm 0.^{\circ}0002$  in declination. Practically all the cluster stars fall on the main branch of the Hertzsprung-Russell diagram, and also show a marked correlation between apparent magnitude and color index. It is well known that space absorption is heavy throughout the general region of this cluster.

## COLOR PHOTOMETRY

Seares and Miss Joyner, continuing their studies of the colors of stars, have finished four related investigations.

(1) A revision of the color indices of the standard polar stars between photo-visual magnitudes 9.5 and 13.8, based on exposure-ratio observations by Baade and Malmquist. The color system remains unchanged; the weights of the individual colors are approximately doubled and the list is increased by about 40 stars.

(2) A recalibration of the effective wave lengths of polar stars measured by Hertzsprung and by Vanderlinden, based on the revised standards described in (1). The purpose was, first, to obtain for the International system an observed relation between the color index of a star and the effective wave length corresponding to its photographic magnitude, for comparison with the theoretical relation for black-body radiators. The agreement proved to be close, a result that checks the effective wave lengths for the International system given in *Mount Wilson Contribution*, No. 685. A second objective was the derivation of data for the reduction of other observations by Hertzsprung and by Vanderlinden.

(3) The preceding investigation required the solution of a statistical problem which becomes important when the error of observation is a considerable percentage of the quantity measured; namely, to find the constants in a linear functional relation, free from systematic error, when the two variables are known only through observed values affected by errors of measurement. The solution lies in a general relation connecting the regression coefficients with the functional constants and the mean error of measurement.

(4) A study of selective space absorption affecting stars in and near the Pleiades cluster, based partly on observations by

Hertzsprung, re-reduced with the results described in (2), and partly on unpublished exposure-ratio measurements by Seares. The color excess  $E$  for cluster stars averages about 0.16 mag. Even with generous allowance for zero-point uncertainty,  $E$  can hardly be less than 0.10 mag. Stars involved in the Merope nebula are redder still, and for groups of field stars, generally much more distant,  $E$  may be 0.3 or 0.4 mag. The absorption is spotty, however, and corresponds roughly to the localized distribution of the extragalactic nebulae seen in the direction of the cluster. Freed from absorption and systematic errors in the spectral types, the members of the cluster seem to be normal main-sequence stars, a result which clears up a long-standing discrepancy in the spectrum-color relation for the Pleiades.

## PHOTOELECTRIC MEASURES OF STARS

Stebbins has continued the measures of colors of stars with a photometer devised and constructed by Whitford, who has been absent on war research since 1941. The observations of about 230 stars in six spectral regions from  $\lambda 3500$  to  $\lambda 10000$  have been completed.

The colors of the typical variable star  $\delta$  Cephei at maximum and minimum phase have been found to match almost exactly the colors of normal supergiant stars of spectra cF4 and cG2, respectively. There is a time lag in the variation of this star in the longer wave lengths, the epoch of maximum or minimum coming more than a quarter of a day later at  $\lambda 10000$  than at  $\lambda 3500$ . This phenomenon must have a direct bearing upon the theory of pulsations in the atmosphere of such a star.

Measures of the nebula in Andromeda have revealed a color difference between the two sides of the apparent ellipsoid. Interpreted as space reddening in this ex-

ternal galaxy, the measures give at once the ratio  $A_{pg}/E = 4.1 \pm 0.4$ , where  $A_{pg}$  is the total photographic absorption and  $E$  the selective absorption on the International scale. This ratio is of fundamental importance in making an allowance for the dimming effect of interstellar material in our galaxy.

An incidental result from the photoelectric observations has been the discovery of a new radiation near  $\lambda 10000$  from the earth's atmosphere. Whether this radiation is from a spectral line, lines, or bands is as yet not known, but it is apparently tens of times as intense as the permanent green auroral line. The infrared radiation may not vary much during a night, but it has changed progressively from year to year. The intensity increased about 90 per cent from 1941 to 1943.

#### COLORS OF FAINT CEPHEIDS IN THE CYGNUS CLOUD

In view of the important role which the four distant Cepheids GL, QY, V 336, and V 343 Cygni play with respect to both galactic rotation and galactic structure, an accurate determination of their color excesses has been undertaken by Baade with

the 60-inch telescope. A sufficient number of photographic and photovisual intercomparisons with S.A. 40 has been obtained for GL and V 343 Cygni. The rest of the program should be completed during the coming season.

#### VAN BIESBROECK'S COMPANION OF BD $+4^{\circ}4048$

Intercomparisons with S.A. 61, for which an accurate sequence down to magnitude 21 is available, gave as photographic magnitude of the companion  $m_{pv} = 19.2$ . The star is red, its estimated color index being  $+1.4$  mag. With a parallax  $p = 0''.170$ , its absolute magnitude is  $M_{pv} = +19.0$ .

#### LIGHT-CURVE OF NOVA PUPPIS 1942

Pettit has continued visual measurements of the magnitude of Nova Puppis with the wedge photometer. Between October 13, 1943 and April 22, 1944 the magnitude decreased from 9.0 to 9.6, the average rate of decrease being 0.38 mag. from October to March, and 0.21 mag. in March and April. The magnitudes of 17 near-by stars have been measured for comparison and future identification.

### STELLAR SPECTROSCOPY

Spectroscopic observations with the 100-inch telescope have been continued without interruption apart from that due to storm conditions, but the reduction in the observing staff has necessitated a slight reduction in the use of the 60-inch telescope. About one-half of the spectroscopic observations with the 100-inch telescope have been made with the coudé spectrograph and the remainder with spectrographs of lower dispersion. Variable stars and early-type stars showing interstellar lines in their spectra have formed an important part of the observing program.

#### RADIAL VELOCITIES

Measurements of the radial velocities of a large proportion of the stars brighter than magnitude 10, judged from their proper motions to belong to the Taurus cluster, were completed by R. E. Wilson before he left the Observatory to engage in military studies. The remaining stars can be measured in about one more observing season. Wilson has added to his program a considerable number of M-type stars of magnitudes 7 and 8 distributed well over the sky which will provide addi-

tional material for studies of space motions and absolute magnitude.

Sanford has completed his observations of the radial velocities of stars of spectral type N and has published the results for 283 stars.

#### DWARF STARS

Observations of the spectra of about 120 dwarf stars with proper motions exceeding  $0''.35$  annually have been nearly completed by Joy. The results which are being prepared for publication will include radial velocities, spectral types, and spectroscopic absolute magnitudes.

In the course of the observations several stars have been added to the list of those showing emission lines of hydrogen and H and K of calcium. One of these, AC  $+31^{\circ}70565$ , is near the dwarf star BD  $+30^{\circ}4824$ . The two stars, according to measures made by observers at the Leander McCormick Observatory, have proper motions equal in amount but differing widely in direction. Parallax measures indicate that the fainter star is the nearer.

#### VARIABLE STARS

Among the many variable stars studied by Joy, Merrill, and Sanford, only a few of the most interesting can be mentioned. The star AE Aquarii, belonging to the SS Cygni class of variables, has been found by Joy to show at minimum of light a normal dG8 type of spectrum with well defined absorption lines which yield the remarkable velocity range of 250 km/sec in a period of two days or less. The changes in velocity resemble those of a spectroscopic binary. SS Cygni and RU Pegasi, on the other hand, have veiled lines, and the much smaller ranges in velocity had previously been ascribed to irregular motions in their atmospheres and to errors of measurement. The emis-

sion spectrum of AE Aquarii resembles that of the other stars of the class, but the bright H and K lines discovered by Vysotsky are exceptionally strong.

The spectra of the 11 stars known to comprise the important T Tauri group of variables have been observed by Joy. Their emission spectrum, best seen at maximum of light, is characterized by great intensity of H and K and by a general resemblance to the spectrum of the solar chromosphere. These stars are the only intrinsic variables which show definite evidence of low luminosity. Four of them are involved in surrounding nebulosity, usually cometary in form, and five others have been found by Joy to have close companions which Dr. Van Biesbroeck has recently measured with the micrometer at the McDonald Observatory.

Joy and Merrill have followed the spectroscopic behavior of the Me variable T Arietis over three cycles. This star, like R Virginis and V Canum Venaticorum, is intermediate between the Mira stars and the irregular M-type variables. The light-changes are somewhat irregular, with a range of about three magnitudes and a period varying between 305 and 340 days. The spectral type varies from M6e to M8, no emission lines being seen at minimum light. In general, the spectroscopic behavior resembles that of the Mira variables. The radial-velocity changes are small and not certainly correlated with phase.

An interesting discovery by Sanford is the presence of the post-maximum lines of  $Fe\,I$ ,  $\lambda 4202$  and  $\lambda 4308$ , of long-period Me-type variables in the post-maximum stage of the N-type variable UV Aurigae, in whose spectrum nebular lines had previously been found. Sanford has also observed bright H and K lines in the Algol variable SS Boötis. These lines apparently belong to the secondary star and should

make possible the determination of its radial-velocity curve.

Observations of typical long-period variables have been continued by Merrill with the coudé spectrograph. To facilitate the reduction of the many-lined spectra of these low-temperature stars, Merrill and Miss Burwell have prepared a card index of numerous metallic lines of low-excitation potential.

#### STARS WITH COMBINATION SPECTRA

Bright-line stars with absorption spectra of late type may be arranged in several groups. Stars of one group, said to have "combination" spectra, present the anomaly of intense high-excitation emission lines superposed upon absorption spectra whose lines arise in gases at comparatively low temperatures. The spectra of the following stars of this kind have been investigated by Merrill during the year: AX Persei, RW Hydrael, BF Cygni, CI Cygni, AG Pegasi, R Aquarii, and Z Andromedae. In BF Cygni the forbidden lines of doubly ionized iron are stronger than in any other spectrum yet observed; the nebular lines of oxygen and neon are subject to surprisingly rapid variations in intensity, marked changes sometimes occurring within 24 hours. Measurements of displacements of the bright lines in several stars have led to the following tentative conclusions: (1) The displacements of most, if not all, lines are variable. (2) A typical range is 30 km/sec. Permitted lines exhibit smaller ranges than forbidden lines. (3) The fluctuations are of long period (one to three years). (4) Maxima and minima of the displacements of forbidden lines occur about one-fifth of the period after the corresponding phases of permitted lines. A working hypothesis to explain the variable displacements is that of pulsations in an extensive, tenuous at-

mosphere in which spectroscopic effects are stratified, the nebular lines being produced in the outer zones.

#### EARLY-TYPE STARS WITH EMISSION LINES

*48 Librae (HD 142983).* An extensive investigation of the spectrum of 48 Librae by Merrill and Sanford, completed during the year, indicated that after a long period of apparent quiescence the outer layers of this star began a remarkable fluctuation which is still in progress. At the extreme velocities, a relative displacement from line to line along the Balmer series was observed. Velocities from metallic lines agreed with those of hydrogen lines near the head of the series. Several facts suggest that the amplitude of the fluctuation increases from the photosphere outward. The bright hydrogen lines apparently come from a layer of hydrogen just above the photosphere. The hydrogen may be released from the stellar interior by some special physical mechanism.

*v Sagittarii.* Coudé spectrograms of *v* Sagittarii obtained by Merrill on the remarkable IV N emulsion showed in emission the great infrared triplet of ionized calcium  $^2S-^2P$   $\lambda 8498, \lambda 8542, \lambda 8662$  (previously photographed at Mount Wilson by H. F. Weaver), and in addition the forbidden lines  $^2S-^2D$   $\lambda 7291, \lambda 7324$ . No previous observations of these forbidden lines either in the laboratory or in astronomical sources seem to be on record. The star is a well known spectroscopic binary of period 138 days, whose brighter, A-type component (the only one observed) has a range in radial velocity of 96 km/sec. The bright lines of calcium and hydrogen do not follow the oscillations of the dark lines, but remain nearly stationary, indicating that they arise in a cloud of gas enveloping the stars. A small difference between the mean velocity from the

bright lines and that corresponding to the center of mass of the binary remains to be explained.

#### DOUBLY IONIZED RARE EARTHS IN THE SPECTRUM OF $\alpha^2$ CANUM VENATICORUM

At the request of Dr. P. Swings, three spectrograms of  $\alpha^2$  Canum Venaticorum extending to slightly below  $\lambda 3100$  in the far ultraviolet were obtained by Adams with the 114-inch camera of the coudé spectrograph. As A. S. King's laboratory results have shown, this region contains numerous lines of the doubly ionized atoms of several of the rare earths. From measurement of the spectrograms, Dr. Swings proved conclusively the presence in the spectrum of this star of lines due to *Eu* III, *Gd* III, *Ce* III, *Sa* III, and *La* III. With the possible exception of *Ce* III, no doubly ionized rare earth had previously been detected in this star.

#### STARS OF TYPES N AND R

Sanford has compared the relative intensities of the cyanogen bands in the red and the violet regions of the spectra of R- and N-type stars. In stars of early R type the blue system of bands is remarkably strong as compared with the red system, whereas for stars of advanced N type the reverse is true. The change is progressive for intermediate spectral types.

#### INTERSTELLAR LINES

Investigations of interstellar lines have

included observations of H and K in early-type stars in open clusters by Sanford with moderate or low dispersion, or when possible with the 32-inch Schmidt camera of the coudé spectrograph.

The very high dispersion of the 114-inch coudé spectrograph has been used by Adams in a continuation of observations of stars of type B with magnitudes brighter than 6.5. The spectrograms cover the region  $\lambda\lambda 3550-4650$  and are used for a study of the structure of interstellar H and K and the occurrence and intensity of the molecular lines of *CN*, *CH* I, and *CH* II. About 125 stars have been observed during the year. The high dispersion is favorable for bringing out faint lines, and relatively few of the stars observed fail to show interstellar H and K. Complex lines are most frequently found in stars in the neighborhood of the constellations of Cygnus and Sagittarius.

In the course of a study of interstellar lines in  $\theta^1$  and  $\theta^2$  Orionis of the Trapezium in Orion, Adams has found in  $\theta^1$  Orionis a secondary component of the strong sharp absorption line of helium at  $\lambda 3888$  which O. C. Wilson discovered in 1937 and which he proved to be due to absorption by helium atoms in the surrounding nebula. The secondary component does not appear in the spectrum of  $\theta^2$  Orionis. Apparently a cloud very limited in size is involved, and it is quite possible that changes will take place as the cloud moves relatively to the star.

#### GALACTIC NEBULAE AND NOVAE

The survey of objects which show *H*  $\alpha$  in emission with little or no continuous spectrum on objective-prism plates has been continued by Minkowski. All together, 49 planetary nebulae and 12 diffuse nebulae have been found. The spectra of these objects and of some faint peculiar

stars included in the material are now under investigation.

#### THE EXPANDING NEBULOSITY AROUND R AQUARI

In last year's report it was stated that the lenticular outer nebulosity of R

Aquarii shows clear signs of expansion. Measurements on the stereocomparator of a pair of plates with a time interval of 16 years indicate that on the assumption of a constant rate of expansion, the nebulosity was ejected 600 years ago. Since spectroscopic observations indicate a velocity of expansion of the order of 80 to 100 km/sec, the resulting distance is 260 parsecs. The corresponding absolute magnitude of R Aquarii at maximum is  $M_{\text{vis}} = -0.4$ , in excellent agreement with the generally adopted absolute magnitude of long-period variables with periods between 300 and 400 days. The expanding nebulosity leaves little doubt that the blue companion of R Aquarii is an ex-nova. With its very low velocity of ejection, it seems to be related to the recurrent novae RS Ophiuchi and T Pyxidis.

*Nova Herculis.* Photographic observations of the shell have been continued by Baade at the Cassegrain focus of the 100-inch telescope. There have been no changes in the remarkable image produced by the [N II] lines  $\lambda 6548$  and  $\lambda 6584$ . The ring structure of the image in the chief nebular lines,  $\lambda 4957$  and  $\lambda 5007$ , has now fully emerged, but it is found that the ring does not extend over the full circumference. There are two gaps at the ends of the minor axis where the ring crosses the bright bar of the [N II] image. Evidently the [O III] emission is suppressed where the [N II] emission is strong.

During the year the shells of two other novae, Nova Cygni (1920) and CP Lacertae (1936), have been found on red photographs ( $\lambda\lambda 6300-6700$ ) at the Newtonian focus of the 100-inch telescope.

*Nova Cygni 1920.* The shell, which is circular and rather bright, has a diameter of 4.3 seconds of arc. On the assumption of a constant rate of expansion with the spectroscopically suggested velocity  $V = 650$  km/sec, the distance of the nova becomes  $D = 1470$  parsecs, and its absolute magnitude at maximum  $M_{\text{max}} = -8.9$ . The fact that Nova Cygni reached a high luminosity in spite of a rather low velocity of expansion makes it doubtful whether the correlation between luminosity and velocity of ejection, suggested by previous data, is significant.

*Nova CP Lacertae 1936.* As was to be expected from the high velocity of expansion, the shell of this nova is now, 8 years after the outburst, already very faint. Its present diameter is 3.5 seconds of arc, which, combined with the spectroscopically determined velocity of expansion  $V = 2000$  km/sec, leads to a distance of 1740 parsecs and an absolute magnitude at maximum  $M_{\text{max}} = -9.2$ .

The spectra of Nova Aquilae 1943 and Nova Cygni 1942 have been observed by Sanford. Both stars are very faint, but their spectra seem to follow the normal course of development. A spectrogram of Nova Puppis 1942 obtained with the coudé spectrograph in November 1943 showed many minima within the wide emission bands. In general, the spectrum resembled that observed seven months previously, but with many differences in details.

Most of the spectroscopic observations of several of the older novae as well as of the nebulosities around Nova Herculis, Nova Persei, and R Aquarii have been made by Humason.

## EXTRAGALACTIC NEBULAE

### RESOLUTION OF MESSIER 32, NGC 205, THE CENTRAL REGION OF THE ANDROMEDA NEBULA, NGC 147, AND NGC 185

Recent photographs on red-sensitive plates, taken by Baade with the 100-inch telescope, have for the first time resolved into stars the two companions of the Andromeda nebula, Messier 32 and NGC 205; the central region of the Andromeda nebula itself; and two new members of the local group of galaxies, NGC 147 and NGC 185, both nebulae of type E. The addition of the latter two objects increases the number of recognized members of the local group of galaxies to thirteen.

The brightest stars in all three systems of the Andromeda group have the photographic magnitude 21.3 and the mean color index +1.3 mag. Since the revised distance-modulus of the group, uncorrected for galactic obscuration, is  $m - M = 22.4$ , the absolute photographic magnitude of the brightest stars in these systems is  $M_{pg} = -1.1$ .

After allowance for galactic obscuration, the distance-modulus of NGC 147 and NGC 185 from magnitudes of their brightest stars is  $m - M = 21.5$ , corresponding to a distance of 205 kpc. The projected linear separation of the pair amounts to 3.5 kpc, their distance from the Andromeda nebula to 40 kpc. The latter value suggests that both objects are companions of the Andromeda nebula. In structure they are inter-

mediate between systems like NGC 205 and the extremely loose Sculptor and Fornax systems. The radial velocity of NGC 185, uncorrected for galactic rotation, is, according to Mayall, -270 km/sec; that of NGC 147 has not been measured.

A discussion of the available data shows that the Hertzsprung-Russell diagram of the stars in early-type nebulae is closely related to, if not identical with, that of the globular clusters. This leads to the conclusion that the stellar populations of the galaxies fall into two distinct groups, one represented by the well known Hertzsprung-Russell diagram of the stars in our solar neighborhood (the slow-moving stars), the other by that of the globular clusters. Characteristic of the first group (type I) are highly luminous O- and B-type stars and open clusters; of the second (type II), short-period Cepheids and globular clusters. Early-type nebulae (E - Sa) seem to have populations of pure type II. Both types seem to coexist in the intermediate and late-type nebulae.

### SPECTROSCOPY

During the year Humason has photographed the spectra of 18 extragalactic nebulae with the low-dispersion spectrograph at the Cassegrain focus of the 100-inch telescope. Most of the objects are of types Sa, Sb, and Sc, fainter than the thirteenth magnitude.

## LABORATORY INVESTIGATIONS

Since his retirement from the Observatory, Dr. A. S. King has been engaged mainly in war investigations but has occasionally carried on some studies in the Physical Laboratory, where his long experience and manipulative skill have been extremely valuable. Such an investigation is described below.

### RELATIVE INTENSITIES OF THE BAND SYSTEMS OF CN

Both the emission and the absorption spectrum of CN have been photographed by King under various conditions of excitation in electric furnace and arc. The red bands of the emission spectrum are found to be strong throughout a wide

range of temperature, and at low temperatures are stronger than the violet bands. In the absorption spectrum the red bands are faint in comparison with those in the violet. This effect, together with a relative strengthening of the red bands when the supply of *CN* is increased, points to a lower transition probability for the red system than for the violet. Such a condition is in agreement with theory in so far as it has been developed for the *CN* spectrum.

One of the bands used in this comparison, near  $\lambda 7900$ , appears in the spectra of many red stars. To facilitate the identification of *CN* in such stars by means of this band, wave-length measures have been made of over 100 band lines which are most prominent in the absorption spectrum of the furnace. These are the lines which should appear most readily in stellar spectra.

The data should be useful in connection with Sanford's spectrograms of N-type stars.

About 14 per cent of the time of the instrument shop has been devoted to regular Observatory work and 86 per cent to construction related to the war. Repairs and maintenance of the instruments and equipment have required most of the time given to Observatory activities, and little new apparatus has been built. The repair of the large crane in the dome of the 100-inch telescope necessitated nearly two weeks of work in Pasadena and on Mount Wilson on the part of several members of the shop force. Albert McIntire has been in charge of the instrument shop, and the design of all new equipment has been carried on by Edgar C. Nichols assisted by Harold S. Kinney.

The time of the optical shop has been occupied almost exclusively with war work

### THE POLARIZING MONOCHROMATOR

As an aid to the use of the interference type of polarizing monochromator for observations of solar prominences, Pettit has made a study of the shift of the transmission band with temperature. Two monochromators which normally transmit the *H<sub>a</sub>* line were observed over a temperature range of 4° to 45° C with a 1-meter concave-grating spectroscope. The temperature was controlled by a thermostat.

The shift  $\Delta\lambda$ , in angstrom units, computed from Sosman's formula for the birefringence of quartz, is

$$\Delta\lambda = 0.71 (t - t_0) + 0.00086 (t^2 - t_0^2).$$

The observed and the computed curves agree for temperatures higher than 25° C, but for lower temperatures the observed  $\Delta\lambda$  is distinctly less than theory requires. At the temperatures at which the monochromators are normally used, observation and theory give, respectively,  $\Delta\lambda = -0.78$  and  $-0.79$  Å per centigrade degree.

### MAINTENANCE AND OPERATION

under the superintendence of Donald O. Hendrix. Since retirement, John S. Dalton has been engaged in the optical shop on the figuring of the large correcting plate for the 48-inch Schmidt telescope under an agreement with the California Institute of Technology.

### BUILDINGS AND GROUNDS

The heavy February snowstorm caused considerable damage to the roofs of the two smaller water reservoirs on Mount Wilson. Repairs were fully completed in June by A. N. Beebe, superintendent of construction, who also assisted in the opening of the Toll Road after the blocking of the main highway.

The absence on military service of Sidney A. Jones, engineer, has added consider-

ably to the responsibility and duties of Kenneth de Huff, who has provided effectively for the maintenance of the instruments and the utilities on Mount Wilson.

A valuable addition to the efficiency of operation of the 60-inch telescope was the

building of a new air-conditioned photographic darkroom, which has been in use for several months. No other important construction on Mount Wilson has been undertaken during the year, apart from the usual repairs.

### THE LIBRARY

Because of the war, observatories and learned societies have issued very few publications during the year; the library has acquired, therefore, very little such material, and has received only 85 periodicals, 27 of which are in exchange. It has added, however, 254 bound volumes; 53 by purchase, 93 by gift, and 108 by binding, making a total of 15,309 volumes. Of the gifts, 79 volumes are the first from Dr. Hale's scientific library, which has now come to the Observatory, to be accessioned and catalogued as part of the Observatory library. No estimate has yet been made of the total number of books in this rich

and outstanding gift, but the large collection includes many rare items, such as the 1600 edition of Gilbert's *De magnete*; first editions of the works of Tycho Brahe, Kepler, and Galileo (*Sidereus nuncius*, 1610; *Macchie solari*, 1613; *Dialogo dei due sistemi del mondo*, 1632, etc.); Scheiner's *Rosa ursina*; a fine run of other astronomical books from the sixteenth through the eighteenth century; and many modern works on astronomy and allied subjects, as well as biographies and studies of the history of science. It is a most valuable and important addition to the Observatory library.

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## SPECIAL PROJECTS: ASTRONOMY

DIRK BROUWER, Yale University Observatory, New Haven, Connecticut. *Program for the determination of systematic corrections to fundamental catalogues from observations of minor planets.* (For previous reports see Year Books Nos. 40 to 42.)

The routine activity continued on the same basis as during the preceding year. Again the Thomas J. Watson Astronomical Computing Bureau devoted all its efforts to war projects and could not undertake any computations for this program. This circumstance and the fact that ephemerides normally furnished by the Copernicus Institut in Berlin were not received made it necessary to continue numerical integrations for four minor planets at Yale Observatory. Dr. Hans G. Hertz was principally in charge of this work, as well as of the computation of ephemerides, until he left the Observatory in November 1943, to join the staff of the U. S. Naval Observatory. Since that date the computations have been continued by Dr. Brouwer and Dr. Gustav Land. The ephemeris of the minor planet (3) Juno was again furnished by Dr. Paul Herget, now at the U. S. Naval Observatory.

The number of plates taken during the year was 539, of which 206 were obtained at the Southern Station in Johannesburg, 72 in New Haven, and 261 at the Allegheny Observatory. The number of plates measured was 146, all by Dr. Land.

S. A. MITCHELL, University of Virginia, Charlottesville, Virginia. *Astronomical studies at the Leander McCormick Observatory.* (For previous reports see Year Books Nos. 38 to 42.)

Further studies toward the classification of the structure of our galaxy have been made during the year. The motions of more than 60,000 stars in the Observatory's general proper-motion program are giving most interesting results. The motions of about half this great number of stars have been measured from McCormick photographs with the 26-inch visual refractor;

Dr. Land completed the orbit correction for the minor planet (57) Mnemosyne. The purpose of this work was the derivation of improved starting coordinates for a new integration. Photographic observations on 83 nights in seven oppositions were included in the discussion. The close dependence of the asteroid program on the Yale zone catalogue program is demonstrated by the circumstance that on only 17 nights could the reduction be made with the aid of positions and proper motions from recent Yale catalogues. The number is so small because the observations were limited to declinations near the equator, where the zone catalogue program is still incomplete. Most of the reductions were, therefore, made with the aid of the star positions from the Astronomische Gesellschaft catalogues without proper motions, the work having been so arranged that corrections may be introduced with little additional calculation when the Yale positions become available.

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the other half of the motions come from a zone in the southern skies observed at the Royal Observatory at the Cape of Good Hope.

The high accuracies of the individual motions of the stars, which cover about seven-eighths of the area of the whole sky, and the great number of stars involved (amounting to about twice the

number contained in the *General Catalogue* published by the Carnegie Institution) will give results of great importance for three separate problems: (1) the motion of the sun with respect to stars of different magnitudes and spectral types; (2) the rotation of the galaxy; and (3) the constant of precession of the equinoxes.

Formerly, it was believed that the field of gravitational force surrounding the sun was intermediate between a force which varies inversely with the square of the distance to the center of the galaxy, and a force which varies directly with the distance. Such fields of force have been observed in other galaxies. Now, with a much larger body of material than has hitherto been available, and with the motions referred to a more reliable fundamental framework than previously, it appears that the stars in our neighborhood move very nearly as they would if the attracting mass were highly concentrated at the center. In other words, the force seems to be approximately inversely proportional to the square of the distance to the center. A conservative estimate by Dr. A. N. Vyssotsky and Dr. Emma T. R. Williams indicates that probably considerably more than 90 per cent of the mass of our galaxy is closer to the center than is our sun. We are apparently situated in an outlying region of our galaxy corresponding to the faint parts of other galaxies which have thus far been impossible to observe for radial velocities and for which, therefore, no fields of force have been derived.

The period of revolution of the stars in our neighborhood around the distant center turns out to be close to what had previously been estimated, namely, about two hundred million years.

It has long been recognized that the sun's motion with respect to the bright early-type stars, the A and F stars, differs

from that with respect to the bright late-type stars, i.e., stars of types K and M.

To explain the difference it has been customary to assume that the motions of the near-by early-type stars were disturbed by the effects of certain widely dispersed "clusters." Now, however, we find that the sun's motion with respect to the *faint* A and F stars is the same as with respect to the *brighter* stars of the same types. Again, its motion with respect to the faint K and M stars agrees with that found from the brighter late-type stars. In other words, the early-type stars as a system are moving with a greater orbital speed around the galactic center than is the system of the late-type stars. If we assume an inverse-square law of force, this behavior may be interpreted to mean that the early-type stars are moving in less eccentric orbits than the late-type stars.

This suggests two interesting analogies between the motions of the stars in our vicinity and those of the members of the solar system. Thus, in each case we find a definite tendency for large orbital eccentricities to be associated with large orbital inclinations. Again, if we confine our attention to stars of the main sequence, the larger eccentricities and inclinations are characteristic of the less massive stars; they are seldom found among the heavier stars of the main sequence. Just so, in the solar system we find that the least massive members, the comets, are characterized by the largest eccentricities and inclinations, and there is a steadily diminishing trend in average eccentricities and inclinations as we progress with increasing mass to the asteroids, then to the less massive planets, and finally to the heavy planets.

Discussion of the motions has not been completed, and from further analysis it is hoped that additional insight will be gained into the structure and dynamics of our galaxy.

## GEOPHYSICAL LABORATORY

*Washington, District of Columbia*

*L. H. ADAMS, Director*

During the past year the participation of the Laboratory in the war effort has continued along the same lines, and on essentially the same scale, as described in the last two annual reports. Our customary work began to be laid aside in June 1941, at which time a comprehensive program of research and development was undertaken at the request of the National Defense Research Committee and under government contracts that have continued to the present time. Somewhat later, there were taken up, also under NDRC auspices, two smaller projects, one of which has been completed. To this work, which involves close cooperation with the Army and Navy, all facilities of the Laboratory have been applied, together with the services of all members of the Laboratory, with the exception of five members of the scientific staff who are on leave of absence without pay for the purpose of taking

important assignments in the armed services or in other war agencies. In addition, about sixty employees have been engaged in various capacities on a temporary basis.

As a result of the investigations that have been carried on, a considerable volume of new information has been forthcoming. It may be of interest to note that the NDRC program of which the Laboratory's main project is a part, and into which it ties closely, has been stated by competent authority to be the most extensive series of investigations ever undertaken on the particular subject. Results have been made available to the armed services and to various government agencies.

A few papers, representing previous work of the Laboratory, have been published in technical journals during the past year. Abstracts of these papers follow.

### SUMMARY OF PUBLISHED WORK

(1079) The binary system  $\text{NaPO}_3$ — $\text{Na}_4\text{P}_2\text{O}_7$ . George W. Morey and Earl Ingerson. *Amer. Jour. Sci.*, vol. 242, pp. 1-6 (1944).

The system  $\text{Na}_2\text{O}$ — $\text{P}_2\text{O}_5$  resembles the systems  $\text{Na}_2\text{O}$ — $\text{SiO}_2$  and  $\text{Na}_2\text{O}$ — $\text{B}_2\text{O}_3$ , previously studied in this Laboratory, in that at the high-alkali end the ortho-compounds crystallize readily; in the intermediate portions glasses are formed which can be crystallized without difficulty; and in mixtures low in sodium oxide the tendency toward glass formation greatly increases. Other duties have made it necessary to stop the projected study of this system, and this paper puts on record results obtained in the partial system  $\text{NaPO}_3$ — $\text{Na}_4\text{P}_2\text{O}_7$ . There is a eutectic at  $552^\circ$  and 0.31 weight fraction  $\text{Na}_4\text{P}_2\text{O}_7$ , at which the

crystalline phases are  $\text{NaPO}_3$  and  $\text{Na}_5\text{P}_3\text{O}_{10}$ , the only binary compound between the two end members.  $\text{Na}_5\text{P}_3\text{O}_{10}$  melts incongruently at  $622^\circ$ , forming crystals of  $\text{Na}_4\text{P}_2\text{O}_7$  and liquid containing 0.495 weight fraction  $\text{Na}_4\text{P}_2\text{O}_7$ . Optical properties of these three compounds are given.

(1080) Some aspects of the melting and crystallization of rock-forming minerals. J. F. Schairer. *Amer. Mineralogist*, vol. 29, pp. 75-91 (1944).

Because of the wartime cancellation of the annual meeting of the Mineralogical Society of America, this address of the retiring president was not presented orally, but the Society asked that it be prepared for publication. The

paper gives a general survey of work on one of the most interesting problems of earth science, the delineation of the physical chemistry of the crystallization of rock-forming minerals from magmas.

The rock magma—a molten solution of complex silicates—is the parent source of the igneous rocks and their minerals. Many igneous rock types may result from the cooling and crystallization of this magma.

Much information on the processes involved in igneous-rock origin has been obtained from detailed petrographic examinations of samples of igneous rocks and from geological field data on the interrelations of the various rocks. However, in order to understand and interpret the complex phenomena of crystallization, with changing mineral assemblages responding to changes in thermodynamic environment brought about by cooling or by changes in pressure, it has been necessary to study the phase equilibrium relations in a large number of silicate systems. Fundamental information concerning the mode of origin of the minerals of the igneous rocks has been obtained through the preparation of silicate melts (simplified artificial magmas) in the laboratory with controlled variations of chemical composition, and through study of the behavior of these melts at equilibrium under a wide variety of temperature and pressure conditions.

Substantial progress has been made in determining the exact chemical compositions and range of compositions and the temperature stability relations of the various rock-forming olivines, pyroxenes (and related pyroxenoids), and melilites. Some progress has been made on determination of the

mutual melting relations among these groups of minerals and between these minerals and other rock-forming species. More progress on both aspects of the problem may be expected from further studies on the quaternary systems that have been investigated at the Geological Laboratory and also at the University of Chicago.

(1081) Why petrofabrics? Earl Ingerson. *Trans. Amer. Geophys. Union*, 25th annual meeting. (In press.)

This paper is primarily an explanation of petrofabrics. It does not discuss theories of rock deformation, nor does it give the details of petrofabric techniques. These subjects have been treated adequately in English by several authors. The present treatment defines petrofabrics and outlines its scope. It then gives a brief history of the development of various branches of the subject.

The uses of the specialized techniques of petrofabrics are discussed as applied to igneous geology, problems in sedimentation, metamorphic rocks, structural problems, and mapping. Examples of actual use are given, and it is pointed out that some of the interpretations would not have been possible without these techniques. In other cases the new techniques corroborated and strengthened interpretations; in still others they saved a great deal of time.

Other types of problems are mentioned in which these techniques are of no value.

Interpretation of grain orientation diagrams is discussed briefly. Published experimental work looking toward more secure interpretation is reviewed, and other projects are suggested.

(1082) Annual Report for 1943-1944.

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# DEPARTMENT OF TERRESTRIAL MAGNETISM

*Washington, District of Columbia*

JOHN A. FLEMING, *Director*

## SUMMARY

Geomagnetic progress during the year July 1, 1943, to June 30, 1944, even though practically all the men of the staff were engaged in war problems, was good. This is attributable to the fact that many of these problems required research utilizing the wealth of observational, theoretical, and instrumental material already in hand through the work and compilations of the Department during forty years.

Of the ten nonprofit contracts undertaken by the Carnegie Institution of Washington in this Department and still active June 30, 1943, four with the Office of Scientific Research and Development and one with the United States Navy were successfully concluded. Continuing or extended contracts include two with the Office of Scientific Research and Development, two with the United States Navy, and one with the United States Army. Two new contracts were made with the United States Navy—one for the Naval Research Medical Center and one for the Naval Hospital—and two more were arranged to begin after July 1, 1944, one of these with the United States Navy for its Naval Hospital and one with the United States Public Health Service for its National Institute of Health.

These contractual obligations require 95 per cent of the services of the available full-time and part-time regular staff of 71 in Washington and at the observatories. The services so rendered without charge to the government during this report-year aggregated some 25,550 hours for the scientific staff and 4050 for the administrative staff; corresponding totals from August

1940 through June 1944 were 116,500 and 20,600, respectively. One hundred and seventy-six temporary employees (including physicists, engineers, mathematicians, computers, machinists, clerks, and guards) were necessary, and the total peak-number of persons at the Department during the year was 247. Besides these, 13 of our regular and 2 of our temporary personnel are on leave of absence either in the armed services or in governmental war agencies.

The development of these projects as regards temporary personnel was again made possible by the action of universities and individual organizations through the generous granting of leaves of absence and provision of technical advice.

## REVIEW OF YEAR'S ACTIVITIES

*Cosmic relations.* The analyses of cosmic data continued to increase solar, geomagnetic, ionospheric, and auroral correlations. The results of last year were further confirmed and the operational value of the conclusions regarding the effects of ionospheric and geomagnetic disturbances on conditions of radio transmission and reception was demonstrated.

A close qualitative correlation was identified between the intensity of auroral displays at Ithaca, New York, and rapid changes in horizontal intensity at Huancayo during the larger storms of the past few years; this was done in cooperation with Dr. C. W. Gartlein, of Cornell University. Abrupt maxima of aurora recorded on a photoelectric photometer (designed by Dr. Gartlein with the financial assistance of the National Geographic

Society) correspond within one or two minutes, in a high percentage of cases, to the most prominent feature of the geomagnetic disturbance—usually a rapid decrease in horizontal intensity.

The Department undertook, upon request, to serve as a clearing house for observations of sunspots by many American observers pending re-establishment of communication with the international center for such data at Zürich, Switzerland. The material collected is made available to interested governments and private laboratories. Analyses of magnetic and ionospheric conditions coincident with outstanding solar activity are enhanced by the more complete solar data thus immediately available.

*Geomagnetic investigations.* Tables applicable in a world-wide sense in the reduction of magnetic observations to epoch were extended to include the years 1942 and 1943. The reduction of field-observations to epoch for over 10,000 stations on land and sea is now about two-thirds complete.

Useful tests for adjusting isomagnetic charts to mutual consistency were evolved. Maps of magnetic anomalies in certain geographical regions are in preparation and several for strategic areas were completed.

The variation in the amplitude of the solar daily variation ( $S_q$ ) with geographical position was derived and found in good agreement with the dynamo-theory of  $S_q$ . A portable magnetograph satisfactory for field-use was developed and tested.

Calculations were made of the effects of electromagnetic induction in sea-water on the field of geomagnetic fluctuations including that of lightning-discharges.

Isolines of equal auroral activity (isochasms) constructed by Fritz for the period 1700 to 1871 for the Northern Hemisphere were revised and extended to

include quantitative results for the auroral zone and regions within. Isolines of equal daily and hourly percentage-frequency of occurrence of visually observed aurora were mapped for the Northern Hemisphere. A derivation is under way of the zone of maximum auroral frequency in the Southern Hemisphere, using geomagnetic as well as auroral data. The extent and frequency of expansions of the auroral zone during magnetic storms are also being studied.

Four portable magnetographs were completed and tests undertaken at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey preliminary to assignment for field-use. Improvements were made in the visual recording magnetograph, of which two are now in use at ionospheric stations.

*Terrestrial electricity.* Atmospheric-electric instruments for studies in ionization were improved. An investigation of the charging-mechanism of the thunderstorm was completed. The theory and limitations of the use of the columnar resistance of the atmosphere were further developed.

Added analyses of the data from observatories, particularly Watheroo, Huancayo, and College, led to satisfactory conclusions regarding several characteristic aspects of the diurnal variations of atmospheric electricity as well as the variations in amount of radioactive matter and in the number of condensation-nuclei in the atmosphere. The relation between recombination-coefficient and the mobility of ions was determined and a formula established.

The analysis for a complete sunspot cycle of earth-current data at the Tucson Magnetic Observatory was made, and striking seasonal changes in the diurnal variation were discussed.

*Ionosphere.* Important contributions leading to improvements of radio-com-

munication circuits resulted from the continued operation of ionospheric recorders at Huancayo, Watheroo, and College, plus the installation of four additional instruments at other sites outside the continental United States.

We are realizing more than ever before the fundamental and binding ties between the ionosphere and the Earth's magnetic field. Individual bits of knowledge gathered from studies of solar activity, aurora, radio blackouts, absorption-measurements, signal-intensities, current-systems, magnetic bays, and many other geophysical factors are gradually being sifted into the proper perspective to provide answers to some of the perplexing problems confronting the geophysicist.

*Nuclear physics.* The 60-inch cyclotron was completed in December 1943, and thus the need for an operating equipment of this type in the region of Washington was met. The cooperation of the National Cancer Institute in continuing assignment of Physicist D. B. Cowie of its staff until January 31, 1944, when he was appointed as one of the regular personnel of the Department, and of the Naval Medical Research Center must be given a large share of the credit for this. For the time being the extensive research-program in nuclear physics must yield to the more urgent need of making the products radioactivated with the equipment useful in the emergency. It may be stated, however, that the work under way will furnish many data of great future value in those researches.

*Observatory- and field-work.* The complete geomagnetic, atmospheric-electric, ionospheric, seismic, and meteorological programs were maintained at the Watheroo, Huancayo, and College magnetic observatories. Special studies relating to geomagnetic, atmospheric-electric, and ionospheric problems were made by the staffs at each observatory. The atmospheric-electric program in cooperation with the United States Coast and Geodetic Survey at its Tucson Magnetic Observatory was continued. We were privileged to have active cooperation with seven observatories abroad.

Maintenance of international magnetic standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was effected through the Division of Geomagnetism and Seismology of the Survey.

Though no field-work other than that at the observatories could be undertaken, it was possible to assist various governments, through loans of magnetic instruments, in undertaking new magnetic surveys and obtaining repeat-observations at established stations.

*Miscellaneous.* Three of the retired staff—J. W. Green, A. Smith, and W. F. Wallis—continued their services and have been of great help.

The field of the Department, perhaps in a unique degree for scientific research, requires team work. The details of the following pages evidence that one and all gave earnest, efficient effort to meet that requirement.

## INVESTIGATIONAL AND EXPERIMENTAL WORK TERRESTRIAL MAGNETISM

Those of the staff at Washington chiefly concerned with geomagnetic research were Fleming, J. W. Green, Johnston, Miss Lange, McNish, Scott, Sherman, Vestine,

Wallis, and Wells, with Bernstein, Mrs. E. B. Crow, Davids, Goff, Shapley, and Zimmer, of the temporary staff. McNish gave his full time to war problems related

particularly to applications of geomagnetism. Torreson was on leave with the Office of Scientific Research and Development. The others named averaged 95 per cent of their time on matters related directly or indirectly to the war effort. It was possible to accomplish some research, and this is reported below.

#### PERMANENT FIELD

The variation with geographic position of the amplitude of the solar daily variation ( $S_d$ ), particularly for the anomalous regions between the geomagnetic and geographic equators, was mapped by Zimmer using observations of  $S_d$  obtained at numerous field-stations as well as at more sparsely distributed magnetic observatories. The amplitude of  $S_d$  is greatest near the geomagnetic equator, and its anomalous increase is most marked at the points of greatest departure of the geomagnetic from the geographic equator, in good agreement with the interpretation by McNish of the dynamo-theory of  $S_d$  due to Balfour-Stewart and Chapman.

Using the method of field-analysis by integrals, Davids developed and tested theoretical computations of vertical intensity from world-charts of horizontal intensity and magnetic declination. Bernstein obtained relationships among derived and intrinsic magnetic elements of world-charts in horizontal intensity and declination, useful in certain features of the construction of isomagnetic charts consistent with requirements of electromagnetic theory. Mrs. Crow constructed a map of the magnetic anomalies in vertical intensity for Pacific areas.

One main contractual activity was the continuation of work of the previous two years in supervising by Vestine, with the nearly full-time assistance of Miss Lange, of about 30 subprofessional and profes-

sional temporary associates. This work was largely along lines which might well be ordinarily normal to the work of the Department, and thus its value will endure in time of peace. The work was greatly facilitated by the cooperation and assistance of many others of the regular and temporary staff, especially by Johnston and Scott at Washington, Seaton and Malich at College, and Corp at Ivigtut.

Late in the year the skilled services of Professor James H. Taylor, of George Washington University, were temporarily obtained for a theoretical examination of the problem of adjusting isomagnetic charts to mutual consistency, the definition of the normal geomagnetic field, and intrinsic properties of mapping contours.

Davids made valuable studies of the changes in magnitude of short-period geomagnetic fluctuations at various ocean-depths, because of electromagnetic induction in sea-water. Data on the geomagnetic effects accompanying lightning-discharges were also collected during a two-year period for the magnetic observatories at Huancayo and Watheroo. Davids also calculated successfully the general shielding-effect of sea-water for these very rapid magnetic fluctuations.

The results of magnetic surveys at stations on land and sea were assembled by Green and Wallis through 1943 for use in this work. Among these were the records of two arctic expeditions (Boyd-National Bureau of Standards Expedition of 1941 to Greenland, Baffin Island, and Labrador; and special expedition of 1943 by Fitzsimmons to Greenland and Labrador).

#### MAGNETIC DISTURBANCES AND COSMIC RELATIONS

The geographic incidence of aurora and geomagnetic disturbances was studied,

using data for over 100 auroral stations observing since 1872 in the Northern Hemisphere. The isochasms of Fritz were revised, using geomagnetic as well as auroral data, and extended to include quantitative results for the auroral zone and the regions within. Isolines of equal percentage-frequency of days of visually observed aurora were prepared for the Northern Hemisphere for days of observation uninfluenced by unfavorable conditions due to daylight and cloudiness. The improved estimate, using geomagnetic data, of the position of the region of maximum auroral frequency was checked and found to be in good agreement with extensive auroral observations of the First and Second International Polar Years, 1882-1883 and 1932-1933, and with those of many expeditions in other years. As was expected, the world-wide incidence of aurora shows a distribution in close agreement with that for geomagnetic disturbance.

Near the center of the auroral zone, as in middle latitudes, there is marked parallelism between auroral frequency and sunspot-number; at the auroral zone the daily frequency of visually observed aurora is practically independent of sunspot-number. Isochasms for sunspot-maximum and sunspot-minimum are in preparation.

Auroral data for the Southern Hemisphere were also compiled, and the position of the southern auroral zone was estimated, using the geomagnetic data of various expeditions.

The hourly percentage-frequency of aurora in the absence of clouds and other conditions unfavorable for observation was derived for some 30 stations. Contrary to certain previous findings, these data, when

arranged on as strictly intercomparable bases as seems conveniently possible, show a fairly simple pattern for the geographic distribution of characteristics of the diurnal variation of aurora. Lines of equal average hourly percentage-frequency of aurora are being mapped for the Northern Hemisphere for several positions of the Sun relative to the Earth.

A study was made of unusual auroral forms observed visually during 1932-1933 at Meanook, Canada. It was concluded that long, thin, feeble, homogeneous auroral arcs, which previously have been rarely observed in northern Europe, and of which six cases were noted at Meanook, appear most frequently and perhaps always in a region some hundreds of kilometers outside the auroral zone. An arc of this type underwent pulsations in light-intensity of period similar to that of simultaneously recorded geomagnetic pulsations.

Six very regular sinusoidal geomagnetic pulsations of period about one minute and amplitude of a few gammas were observed by Sherman, Vestine, and Goff, using special equipment, at Turtle Mound, Florida, within a period of two weeks of operation. Hence these pulsations, of type previously occasionally noted near the auroral zone, appear also in middle latitudes, where they may appear much reduced in average amplitude.

#### INSTRUMENTAL DEVELOPMENTS

Vestine, Sherman, Shapley, and Steiner developed and constructed two visually recording magnetographs, now in use in the field. There was also developed by Vestine and Sherman a portable magnetograph, of which four were constructed.

## TERRESTRIAL ELECTRICITY

The aggregate time spent on war-research during the report-year was about the same as during the last report-year. Rooney resumed his investigations in geo-electricity on December 1, 1943 (after leave of absence in experimental developments with the Navy), Sherman was engaged in war-research the major part of the time, and Torreson gave full time to such work. Gish and Wait attended to most of the necessary routine and did some research and consultation on war problems.

## ATMOSPHERIC ELECTRICITY

*Development of instruments and methods.* Further improvements were effected in ionization-meters (Gish and Sherman) in order to meet the exacting demands of work which is being done jointly with Professor V. F. Hess. These meters, with minor modifications, hold promise of being convenient and effective for certain other applications, especially where the examination of many radioactive samples is required. The interpretation of some aspects of the columnar resistance of the atmosphere, indicated by atmospheric-electric data, was continued (Gish), and a paper entitled "Evaluation and interpretation of the columnar resistance of the atmosphere" was completed.

*The charge-generating mechanism of the thunderstorm.* Considerable study was made of some aspects of mechanisms proposed to elucidate the generation of charge in the thunderstorm. Quantitative examination (Gish) brings into question essential portions of all those proposals which have not yet been definitely refuted by qualitative evidence. Certain gaps in the array of information which is required to prove or disprove a proposed mechanism were pointed out, and reasons for regard-

ing the missing information as important were indicated.

The electric cycle of the thunderstorm may be regarded as consisting of the following steps: (a) the initial small-scale separation of charge, in which individual particles of precipitation and cloud-particles become charged, and during which ions (submicroscopic particles, or particles of about molecular size, with one element of charge) may possibly be formed in the electrically active center of the storm-cloud; (b) the large-scale separation of charge, in which particles or ions charged with electricity of one sign are separated from those of the other sign to distances of several kilometers; this may consist of several steps; (c) the initiation of the lightning-discharge, namely, the mobilization of the charges on individual drops, widely distributed throughout some cubic kilometers of space, at such a rate and in such a quantity as to supply the lightning-discharge proper; (d) the lightning-discharge, comprising several identifiable steps which follow the foregoing stage and complete the electric cycle. This last phase of the cycle is now much more clearly elucidated than the other steps. It was steps (a), (b), and (c) which were the subject of this study.

Of the well known initial charging processes, that which occurs upon the collision of ice-particles seems likely to be the most consistent with the facts which are now known. But no quantitative study of this process has yet been made. From some available information about the charge developed by the collision of dust-particles, however, it appears that unless the initial separation of charge is much greater in the case of ice than in that of dust, or unless the concentration of particles (mass per cc) is much greater than any

seen reported in reference-books on meteorology, the initial separation of charge would occur at a rate too slow to account for the apparent rate of regeneration of the cloud-charge, unless this stage of charge-separation occurs in a region of turbulence.

It also appears doubtful whether in straight winds the large-scale separation of charge can occur at the rate which seems to be required. From this study the following tentative views developed: (a) that the initial separation occurs in a region of turbulence between two air-masses or air-cells; (b) that a first stage in the large-scale separation (an intermediate-scale separation) consists in a centrifuge-like action of the eddies in the turbulent region; and (c) that after this intermediate-scale separation, charges of one sign and size are introduced into an air-stream having a velocity which may differ in both magnitude and direction from that into which the particles of opposite sign, and doubtless different size, have been introduced. Apparently this sequence of processes would be more responsive to windiness and would be capable of separating charge at a considerably greater rate than is possible in a straight wind.

*Ionization of the air by bubbling water.* In view of the application to thunder-storm electricity, it seemed desirable to test air from the vicinity of bubbling water. Lord Kelvin (Proc. R. Soc., vol. 57, p. 335, 1894) first showed that air bubbled through water carried a negative charge. From experiments by Alty and later by Currie and Alty (Proc. R. Soc., A, vol. 112, p. 235, 1926; vol. 122, p. 622, 1929) on the motion of air-bubbles through water in an electric field, it was concluded that negative ions collect in the water around the bubble, and that the positive ions must occur deeper in the water, since the water as a whole is neutral. It was also concluded that the charge on a bubble in very

pure water is  $5.4 \times 10^{-4}$  ESU, and that the critical radius is 0.033 cm, the charge being constant for a radius down to this critical value.

In the experiment the small-ion counter was employed as the detecting and measuring instrument for the ions from the bubbling water. Air was forced through water to produce bubbling at the surface, and the air passed upward through an air-duct into the ion-counter. The results showed that practically no positive ions, but a large number of negative ions were present in such air. The test on the mobility of the ions showed the presence of two groups of ions about equal in number; the mobility of the one group being about half that of small ions (or 0.8 cm/sec/V/cm), and that of the other group about one-tenth that of small ions (that is, about 0.15 cm/sec/V/cm). The total number of unit charges coming from the bubbling water was about 3500 per cc or (since the air-flow through the apparatus was a liter per second) about 3,500,000 charges per second.

These ions could be the result of larger droplets with many unit electric charges or of smaller droplets with one or a few unit electric charges. If large droplets were present, they would be expected to carry off water as they left the vessel without materially adding to the relative humidity of the surrounding air. Should the droplets be sufficiently small—that is, of molecular dimensions—they would account for an increase in relative humidity but would not otherwise cause water to be carried away. It was found that additional water was lost at a rate of  $3.2 \times 10^{-3}$  gram per second. From this rate, the rate at which electric charges are collected by the ion-counter, the mobility of the ions, and the wind-velocity through the air-duct, the greatest possible radius of the ions and the average charge per ion

may be computed. The results indicate that the limiting radius of the ion is  $2.8 \times 10^{-8}$  cm and that each ion must carry about 2,000,000 unit-charges—the latter value of the same order as that found by Currie and Alty, although the radius is of an order of magnitude smaller than that found by them. Though the methods differ radically from those employed by Currie and Alty, they confirm their findings regarding the number of charges carried by ions from bubbling water.

*Diurnal variation of atmospheric-electric elements in winter at Watheroo.* Last year's report described the diurnal variation of the atmospheric-electric elements for two types of days during winter at Watheroo. For the first or normal-day type, low wind-velocities prevail during the night and moderate velocities during the day; for the second type, the wind remains comparatively high during both night and day. Further investigation (Wait) of the data for days of the second type gives additional evidence concerning the cause of the diurnal variation in conductivity (a) of the lower air and (b) throughout a vertical column. It now seems possible to account for both (a) and (b) during the period 09<sup>h</sup> to 17<sup>h</sup>, when the wind is high, on the following assumptions: (1) During this period the atmosphere is homogeneous throughout a vertical column up to a height of about 1480 meters as regards condensation-nuclei ( $N_A$ ) and the radioactive content of the air. (2) The radioactive matter consists entirely of thorium products in equilibrium with the emanation, each of which decays in its normal manner. (3) The condensation-nuclei content of the air remains constant with time at about 1500 per cc, in agreement with the average number observed in winter. (4) The value of the combination-coefficient ( $\beta$ ) between small ions and condensation-nuclei remains con-

stant at  $3 \times 10^{-6}$  during this interval. (5) The rate of small-ion production ( $q$ ) is given by the equation  $q = (\alpha n^2 + \beta N_A n)$ , where  $n$  is the number of small ions per cc in the air and  $\alpha$  is the recombination-coefficient of small ions with a value of  $2 \times 10^{-6}$ . (6) Cosmic rays account for 1.5 ion-pairs per cc throughout the 1480-meter vertical column, and the rate of production remains constant throughout the entire 24 hours of the day.

These six assumptions permit calculation of a value of  $q$  for each hour and thence the values of the conductivity ( $\lambda$ ) of the lower air from hour to hour and of the total resistance ( $R_w$ ) of a vertical column. Values so computed show good agreement with those observed for the interval when the wind-velocity is comparatively high.

The computed values on these assumptions become increasingly too small, however, as compared with the observed values on days of the first type, when the wind-velocity goes down after 17<sup>h</sup>. The computed values of  $R_w$  compare favorably with those observed until around midnight, but become increasingly too great thereafter. It appears necessary, therefore, to alter somewhat the first four assumptions for the interval from 17<sup>h</sup> to 09<sup>h</sup> when the wind-velocity is low, as follows: (1) After 17<sup>h</sup>, when the wind quiets down, the layer of the atmosphere below the 1480-meter level separates into two horizontal layers, one (a) between 0 and about 220 meters above the ground, and the other (b) between 220 and 1480 meters. (2) Thorium emanation from the soil and its products accumulate in layer (a) and are more or less uniformly dispersed vertically. (3) The total number of condensation-nuclei in a vertical column remains the same as during 09<sup>h</sup> to 17<sup>h</sup>, but the number in layer (a) is increased because nuclei settle from layer (b); the average number in layer (b) is around

600 per cc and in layer (*a*) around 6000 per cc. (4) The value of  $\beta$  in layer (*b*) remains at  $3 \times 10^{-6}$ , but in layer (*a*) it increases to around  $4 \times 10^{-6}$ .

The value of  $q$  in layer (*b*) accordingly continues to decrease owing to the continued decaying of the radioactive matter; the conductivity of layer (*b*), however, does not decrease greatly, owing to the diminished number of condensation-nuclei. The value of  $q$  in layer (*a*) becomes very large owing to an accumulation of radioactive matter there; the conductivity of layer (*a*), however, increases only moderately because of the increased condensation-nuclei content.

Thus we may account quantitatively for the observed hourly values, during days of the second type, of both  $\lambda$  and  $R_e$  and therefore of the air-earth current and the potential-gradient during winter for those days when the wind remains high throughout the 24 hours.

To account for the first or normal-day type with low wind at night, we must further assume that, during the calm period of the day, the radioactive matter is not uniformly distributed throughout layer (*a*), but is more concentrated near the ground and falls off in concentration with height.

*Accumulation of radioactive matter in the lower air at College, Alaska.* In view of the particular type of diurnal variation found for the positive conductivity at College, Alaska (see K. L. Sherman, *Terr. Mag.*, vol. 42, pp. 371-390, 1937), we might expect to find that an important factor in its production is a variation in the amount of radioactive matter in the air. Analysis of the data indicates that radioactive matter in the air is more plentiful at College during the calm than during the windy part of the day, as at Watheroo and Washington. The negative conductivity, on the other hand, particularly during

May to August, has a diurnal variation of an entirely different character. Gish and Sherman (*Terr. Mag.*, vol. 45, pp. 173-190, 1940) showed this element to be greatly influenced by the electrode-effect. The value, therefore, is somewhat dependent upon the value of the electric field of the Earth as well as upon the velocity of the wind. Graphs of the data actually show that the diurnal variations of wind-velocity and of negative conductivity are similar. One should expect, therefore, to find little evidence of accumulated radioactive matter in the diurnal variation of negative conductivity. An extended analysis shows, however, just as for Watheroo and for Washington, the effect of an accumulation of radioactive matter near the ground during the period of the day when the wind is low, and a reduction in amount of radioactive matter when the wind increases in velocity.

*Accumulation of radioactive matter in the lower air at Huancayo.* A procedure similar to that just described for the College data was followed for Huancayo. There was no group of days with very high wind during the night and early morning hours; days were grouped, therefore, according to whether the wind rose, or not, to an evening maximum. There is usually a sharp maximum in wind-velocity around 17<sup>h</sup> to 18<sup>h</sup> and a low, flat minimum around 10<sup>h</sup> to 11<sup>h</sup>. A second group of days was selected when no evening maximum was present; in this group the wind continued low throughout practically the entire 24 hours, but was somewhat higher during the early morning. Analysis indicates that, contrary to what was found for Watheroo and College, calm conditions at Huancayo do not favor the production of higher conductivities, but rather the reverse. These results confirm Gish's contention that nuclei are brought down from higher layers to the

lower layers. Incidentally, almost no differences between the positive and the negative conductivity were found for either group of days.

*Measurements of ion-mobility by ion-counter.* Tests (Wait) in measuring the mobility of ions with an ion-counter emphasized the importance of maintaining the central electrode near ground-potential. For heavily ionized air the usual measuring equipment must be modified by the use of a resistance of sufficiently low value, connected in parallel with the electrometer.

*Recombination-coefficient of ions and variation with mobility.* The rates at

The value of slope  $S$  is 0.74, of  $\log C$  is 0.257, of  $A$  is  $10^9$ , and of  $B$  is  $10^4$ . The value of  $\alpha$  for the large ion ( $1.4 \times 10^{-9}$ ) determined many years ago at Dublin University (Proc. R. Irish Acad., A, vol. 33, pp. 58-74, 1916), and heretofore generally accepted, appears to be too small.

#### GEOELECTRICITY

The reduction of earth-current records, interrupted because of diversion of personnel to war work, was resumed in December (Rooney). Final reduction of the Tucson earth-current records from July 1940 to February 1943, and the compilation

TABLE 1  
RECOMBINATION-COEFFICIENTS AND MOBILITIES FOR VARIOUS CLASSES OF IONS

Recombination-coefficient, $\alpha$	Mobility, $k$ (cm/sec/V/cm)	Class of ion
$2.0 \times 10^{-6}$	$15.0 \times 10^{-1}$	Small, molecular ion of the atmosphere
$0.7 \times 10^{-6}$	$5.0 \times 10^{-1}$	Intermediate ion of the atmosphere
$7.6 \times 10^{-8}$	$2.5 \times 10^{-2}$	
$1.1 \times 10^{-8}$	$1.9 \times 10^{-3}$	
$3.1 \times 10^{-9}$	$3.2 \times 10^{-4}$	Large or Langevin ion of the atmosphere

which ions recombine and at which they travel in response to an electric field diminish as the size of the ion increases. Whereas determinations for small molecular ions of the recombination-coefficient ( $\alpha$ ) and of mobility ( $k$ ) are numerous, those for larger ions are few, and no investigation appears to have determined both  $\alpha$  and  $k$  for the same ion. During the past year simultaneous measurements (Wait) were made for  $\alpha$  and  $k$ , for the small ion having a mobility around 1.5 cm/sec/V/cm, for the large ion having a mobility around  $3 \times 10^{-4}$  cm/sec/V/cm, and for several groups of ions having intermediate mobilities (see table 1).

The data of table 1 may be represented by a straight-line equation of the form

$$\log A\alpha = \log C + S \log Bk$$

of monthly and yearly averages for the full 11.5-year period of registration at that place, have been completed. The earth-current data from Watheroo and Huancayo have also been brought up to date by reduction of the records from July 1940 to January 1944. The most pronounced feature of the records obtained during this interval at all three observatories is the low activity in earth-current flow characteristic of periods near a sunspot-minimum.

Further study is being made by Rooney of the seasonal changes in the diurnal variation of earth-current potential-gradient recorded at Tucson. The seasonal variation at this station exhibits several unusual features, most striking of which is a large increase in the magnitudes of

both components in January. Records from the individual years have shown that the magnitude of the diurnal variation in January is invariably much greater than that in December or in February and is even equal to, or greater than, that in the summer or equinoctial months. At the same time the character of the diurnal variation and its phase-relationship is the same as that for the other winter months. With the data from all 12 winter seasons at Tucson, it is possible to follow this increase in activity over 5- or 10-day intervals.

The increase is found to begin near the winter solstice, to reach its maximum between January 5 and 10, and to disappear early in February. The cause of this unusual feature is not yet clear, but since a similar phenomenon has been noted in the magnetic variations at Tucson, it is unlikely that it is due to changes in resistivity or to other factors which might affect current-flow alone. In this connection it is hoped that direct comparison of the earth-current and magnetic data will be enlightening.

### THE IONOSPHERE AND ITS RELATIONS TO GEOMAGNETISM

#### WEATHER OBSERVATIONS

During the past year, the major effort of the Ionospheric Section has been devoted to the practically simultaneous establishment of four new ionospheric stations outside the continental United States. The technical crews for each new station were trained as working groups. Each party was made responsible for the entire complement of equipment and supplies. Apparatus was constructed or modified as required; field-tests were conducted to reproduce actual operating conditions; and each group actively supervised the packing of its entire shipment for export.

Operation of the CIW automatic multi-frequency-recorders was continued at Huancayo, Watheroo, and College. Performance was essentially continuous except for short intervals required for maintenance. Tabulations and analyses were maintained current in all phases of the program, and results were promptly exchanged with authorized agencies. Ionospheric measurements from Huancayo and Watheroo are now continuous for more than half a sunspot-cycle without any significant instrumental changes. These extended series of measurements have been

particularly helpful in analyses of long-term trends and in preparation of forecasts of radio propagation-conditions.

As a result of recommendations adopted at the International Radio Propagation Conference (April 17 to May 5, 1944), revised instructions have been issued to all stations, to make possible uniform interpretation and reporting of ionospheric characteristics.

#### RESEARCH AND DEVELOPMENT

The coordinated program of recording and analyzing solar-terrestrial relations was continued and extended, with promising results, which were applied to the prediction of magnetic and radio disturbances up to a week or more in advance. New techniques and improved instrumentation are giving encouraging performance.

In addition to the testing of equipment and training of personnel, activities at the Kensington Ionospheric Laboratory were directed toward the construction of field-intensity recorders for Huancayo, and the performance of special propagation-measurements on medium-frequency signals at oblique incidence. The "burst"-phe-

nomena first reported in the ultra-high-frequency (UHF) bands (45 Mc) by the Federal Communications Commission were successfully demonstrated on repeated occasions, and continuous recordings of this effect were attempted. Some consideration was given to the connection between the UHF bursts and ionization produced by meteor-trains.

Considerable progress has also been made in the improvement of manually operated ionospheric recorders. Output has been multiplied, losses have been reduced, units have been simplified, and antenna requirements have been minimized. Promising studies have also been pursued to determine relations between sporadic *E*, aurora, radio blackouts, and conditions of radio propagation, especially in the polar regions.

#### POST-WAR PLANS

Following are some of the general subjects on which important contributions may be expected in the post-war period: (1) measurement of intensity of Earth's magnetic field in the ionosphere near the magnetic equator; (2) mapping of world-wide characteristics of ionospheric regions

with explanation of anomalous features; (3) critical examination of sporadic *E*-region ionization to determine nature, extent, and relation to solar corpuscular radiation or other causes; (4) improved understanding of solar and terrestrial relations determined from coordinated program of solar, ionospheric, and magnetic observations and analyses; (5) absorption-measurements to determine effect of ultraviolet and corpuscular absorption on the ionosphere and radio communications both near the auroral zone and at low latitudes, and to compare such effects with magnetic current-systems; (6) investigation of the "burst" phenomena on the ultra-high frequency-modulated and television bands to determine relation with meteors or sporadic *E*.

#### GENERAL

An active part was taken in the International Radio Propagation Conference held at the National Bureau of Standards April 17 to May 5, 1944. Work was started on the new ionospheric laboratory at Huancayo, which is to house the multi-frequency equipment and the field-intensity recorders.

#### MAGNETISM AND ATOMIC PHYSICS

Tuve, Hafstad, Roberts, Green, Heydenburg, and Abelson (resigned December 31, 1943) of the nuclear-physics group were assigned or engaged full time during the report-year on war-research activities or in the services. Cowie (assigned from the National Cancer Institute until January 31, 1944, when he was appointed physicist and biophysicist) had charge of the cyclotron with the assistance of Ksanda, P. Johnson, Buynitzky, and F. R. Nichols (in U. S. Navy from October 24, 1943). We were fortunate in having associated with the staff Dr. P. C. Ho (from January

1 to May 21, 1944) and Dr. J. S. Mendousse, captain in the French Army, whose services have been made available through the courtesy of the French Military Mission in Washington (from January 1, 1944). Despite the serious depletion of personnel and thanks to the splendid work of Cowie and his colleagues, the cyclotron has been in operation since January 1944. Lack of personnel, as in the previous year, made necessary the discontinuance of further improvements in, and operation of, the large static generator in the Atomic-Physics Observatory and the small one in

the Experiment Building, as well as the fundamental researches in nuclear physics.

### CYCLOTRON

The 60-inch cyclotron was completed and placed in operation. With the stimulation provided by the United States Naval Medical Center at Bethesda by the loan of several large no. 893 vacuum-tubes, the radio-frequency system was available for its full ultimate load, and a period of out-gassing of the entire system was carried out in order to build up radio-frequency voltage on the dees. Early in December the vacuum-system, magnet, control-system, and all power-supplies with the exception of the ion-source were complete and ready for operation. An ion-source with a vacuum-lock was installed, and on December 31, 1943, all components of the cyclotron were put into operation together for the first time. A quartz probe was slid between the dees almost up to the ion-source, and with the equipment all in operation, with the exception of the deflector, the magnetic field was varied so that the calculated resonant condition would be reached. A bright fluorescence was observed on the quartz rod the first time the magnetic field was raised high enough to obtain resonance, and with the extraction slowly of this rod toward the periphery of the dees it was evident that we had located our first deuteron-beam. Adjustment of dees and magnetic shimming increased the intensity of the beam so that quartz rods were no longer suitable for beam-adjustments, since they were sheared off by the beam itself even near the peripheries of the dee. The beam-current was steadily increased until 300 to 400 microamperes of deuterons on internal

probe-targets were measured at resonant conditions calculated to be 15.8 million electron-volts of deuterons.

Various target-holders and vacuum-locks to permit the introduction and withdrawal of targets without loss of the vacuum were made. Bombardment of many substances was carried out and extremely high yields of radioactivity were obtained.

Some parasitic trouble in the radio-frequency power-amplifier delayed the date of final exceedingly stable operation, but at present the cyclotron is operated daily by one individual with only slight adjustments every hour or so.

With the completion of the cyclotron for operation, its use for war-research became possible. Contracts for its use are already under way for the Navy, Public Health Service, and other government and educational organizations. The particular skills and qualifications of Cowie, Mendousse, Ksanda, Johnson, and Buy-nitzky permit the full utilization of the instrument.

A fully equipped laboratory for chemical manipulations is centered in two separate regions depending upon the nature of the radioactive procedure. Measurements and standardization of radioactive samples are done in the underground measuring-room except for certain samples whose nature restricts them to a second measuring-laboratory.

### MISCELLANEOUS

As in 1943, the Annual Conference on Theoretical Physics had to be deferred because of limitations of time and travel. It has been possible, however, to hold many conferences with interested co-workers.

## FIELD-WORK AND REDUCTIONS

## LAND MAGNETIC SURVEY

Results of recent surveys were revised and prepared for inclusion in volume VIII of the Researches of the Department of Terrestrial Magnetism, giving results of observations on land during 1927 to 1943. As heretofore, these results have been made available for use to various agencies of the government engaged in active prosecution of the war and to collaborating organizations. Correlations of comparisons of the many instruments used at observatories and in the field were discussed, and resulting final corrections on international magnetic standards were adopted.

Extensive reductions of secular changes in magnetic elements for various points of the Earth were made for four epochs at ten-year intervals beginning with 1912.5. In this work careful attention was paid to correction of the results of field-stations and observatories for geomagnetic variations not associated with the Earth's main field, using the tables of corrections described in last year's report.

New methods for adjustment of geomagnetic charts to mutual consistency in the various elements have been evolved and found satisfactory by test.

There was active cooperation in magnetic surveys, through the loan of field-instruments and equipment to six observatories in South America, South Australia, Northern Australia, New Zealand, British East Africa, and the United States, as well as to the Army Air Force. International magnetic standards and corrections thereto were maintained as heretofore in cooperation with the United States Coast and Geodetic Survey at the Cheltenham Magnetic Observatory.

## FIELD-OPERATIONS AND COOPERATIVE SURVEYS

*Africa.* Dr. A. Walter, Director of the British East African Meteorological Service, using CIW magnetometer and inductor 13, continued occupation of stations in Tanganyika Territory, Nairobi; he also obtained monthly observations at Kabete providing estimates of secular change.

At Hermanus Observatory, where geomagnetic secular change is great, Dr. A. Ogg, of the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa, obtained frequent measurements using CIW magnetometer-inductor 17. Annual values to 1943 and results for land stations were received through G. Heinrichs, of Elisabethville Magnetic Observatory, Belgian Congo. Mr. Heinrichs also made intercomparisons of his absolute instruments with those at Hermanus Observatory.

*Australia.* Cooperative work was maintained with the Aerial, Geological, and Geophysical Survey of Northern Australia of the Commonwealth's Department of Supply and Development at Canberra. Chief Geologist J. M. Rayner and Mr. R. S. Richardson continued surveys using CIW magnetometer-inductor 18. Maps were constructed and results compiled, respecting magnetic elements and their secular changes, "based almost entirely on observations made by the Department of Terrestrial Magnetism." In this work assistance was rendered by Observer-in-charge W. C. Parkinson of the Department's Watheroo Magnetic Observatory.

Latest corrections in standards for CIW magnetometer 6 and dip-circle 226, used in the survey operations of the Adelaide Observatory of South Australia, were compiled and forwarded to facilitate final compilations of observations by Astronomer G. F. Dodwell.

*New Zealand.* Director H. F. Baird of the

New Zealand Magnetic Survey, New Zealand Department of Scientific and Industrial Research, furnished results of over 100 field-stations obtained using CIW magnetometer-inductor 27.

Dr. E. Marsden, Secretary of the New Zealand Department of Scientific and Industrial Research, used a newly developed CIW instrument to obtain magnetic measurements in the Pacific Ocean and New Zealand.

*North, Central, and South America.* CIW magnetometer-inductors 26 and 28 remained on loan to the United States Coast and Geodetic Survey for resurveys in the Western Hemisphere, financed by the United States Department of State. Stations were occupied as follows: Brazil, 17; Panama, 2; Costa Rica,

2; Nicaragua, 5; Honduras, 4; Guatemala, 6; Chile, 5; Peru, 6. At the conclusion of the second survey, now under way in South America, CIW magnetometer-inductor 28 will be placed at the disposal of the Division of Geodesy, Military Geographic Institute, Uruguay; Major S. Graceras, the Chief of that Division, was instructed at the Department of Terrestrial Magnetism in instrumental and land-survey techniques; he expects to complete the first-class magnetic survey at some 60 stations in Uruguay.

*Arctic.* The Department cooperated, through the loan of magnetometer-inductor 16 and auxiliary equipment, and through the training of an observer, in a completed survey within arctic regions.

#### \* OBSERVATORY-WORK

The Section of Observatory-Work continued under the charge of Johnston with the assistance of Scott and Miss Balsam. Wait continued the consideration of atmospheric-electric data from our observatories, and McNish and Torreson were engaged on war work. The men in residence at the observatories are noted in reports for the individual stations.

Despite increased time devoted to the war effort, the magnetic reductions and compilations for the observatories at Watheroo, Huancayo, and College were maintained current. The computed values for the year 1943 were immediately utilized in the reduction of observed magnetic elements at field-stations to mean of day, mean of month, and mean of year.

The magnetic, earth-current, and ionospheric programs at the three observatories were continued. Analysis of the observations was currently maintained, and weekly summaries of magnetic and ionospheric data, predicted values of maximum usable frequencies for various distances, and current forecasts of conditions having prob-

able effects on radio communications were supplied.

Continuous records of the three magnetic elements and of heights of the ionosphere by means of both multifrequency and fixed-frequency transmissions were obtained at Watheroo, Huancayo, and College. Atmospheric potential-gradient, positive and negative conductivity of the atmosphere, earth-currents, solar observations by means of a Hale spectrohelioscope, and meteorological elements were recorded at Watheroo and Huancayo. A cosmic-ray meter and a three-component seismograph were operated at Huancayo. An elaborate program of auroral work was continued at College.

The reductions of the magnetic observations at Watheroo and Huancayo were completed for the year 1943. The observations for moment of inertia of the long magnet and stirrup of CIW magnetometer 7, which is used at Watheroo to determine horizontal intensity, were examined for the period of operation since 1919. Frequent comparisons have also

been obtained since then with others of our magnetometers during field-expeditions. As a result of the analysis, revised corrections on International Magnetic Standard were adopted. The revised annual values for the period 1919-1941 were published in the June 1944 issue of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, and supersede those heretofore published in these annual reports. The mean annual values of the magnetic elements for all days of 1942 and 1943 are shown in table 2.

337-388, from ten observatories were compiled during the report-year.

The compilation of the annual values for the world's magnetic observatories of the elements *D*, *H*, *Z*, *I*, *X*, *Y*, and *F* for all days was continued by Fleming and Scott. The Thesaurus of Annual Values completed during the year included all observatories from Valencia (51°9' N) to Little America (78°6' S). A few values for the year 1943 were supplied and published. The values were promptly used in the project for reducing magnetic field-

TABLE 2

ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED ON MAGNETOGrams FOR ALL DAYS, 1942 AND 1943

YEAR	DECLINATION, <i>D</i>	INCLINATION, <i>I</i>	INTENSITY-COMPONENTS					LOCAL MAGNETIC CONSTANT, <i>G</i>	
			Horizontal, <i>H</i> (γ)	Total, <i>F</i> (γ)	North-south, <i>X</i> (γ)	East-west, <i>Y</i> (γ)	Vertical, <i>Z</i>		
WATHEROO MAGNETIC OBSERVATORY									
1942.....	3° 08'2 W	64° 24'8 S	24705	57203	24668	-1352	-51593	35718	
1943.....	3 04.4 W	64 25.4 S	24718	57254	24682	-1325	-51643	35745	
HUANCAYO MAGNETIC OBSERVATORY									
1942.....	6 45.3 E	2 12.5 N	29438	29460	29234	3463	1135	29443	
1943.....	6 40.0 E	2 11.5 N	29400	29422	29201	3413	1125	29405	

The extensive program of collecting data on geomagnetic activity from world magnetic observatories was continued. Co-operating observatories supply indices of activity for each day, covering the eight successive three-hour periods during the Greenwich day. The indices range from 0, very quiet, to 9, extremely disturbed. Activity reports have been received from 27, 28, 24, and 25 magnetic observatories for the years 1940 to 1943, respectively.

Weekly reports from ten observatories have continued to be issued. Reports of Geomagnetic Activity, DTM CIW Nos.

observations to mean of sunspot-cycle and to epoch, mentioned elsewhere in this report.

Cooperation in magnetic and atmospheric-electric work was continued with various magnetic observatories. The United States Coast and Geodetic Survey maintained our International Magnetic Standards at Cheltenham Observatory and continued the program of atmospheric-electric observations at Tucson Observatory. The Danish Government continued the operation of the Godhavn and Ivigtut magnetic observatories in Greenland.

## OPERATIONS AT OBSERVATORIES

*Watheroo Magnetic Observatory, Watheroo, Western Australia.* The Watheroo Magnetic Observatory is situated in latitude  $30^{\circ} 19' 1$  south and longitude  $115^{\circ} 52' 6$  east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was in continuous operation. Weekly determinations of the values of the base-lines for the three elements were made. The scale-value of the horizontal-intensity variometer was controlled by monthly determinations, using the method of magnetic deflections. Daily determinations of the scale-value of the vertical-intensity variometer were made by passing a current of known strength through a coil surrounding the variometer.

Redeterminations of the azimuths of fixed marks from the observing piers in the absolute observatory were made.

The la Cour rapid-running magnetograph was in operation throughout the year; monthly determinations of the scale-values of the horizontal- and vertical-intensity variometers were made, using the electrical method. The monthly scale-values for 1943 for both the Eschenhagen and la Cour magnetographs are shown in table 3.

The preliminary values for the annual changes in the magnetic elements for all days of 1943, as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination  $+3.8$ ; horizontal intensity  $+13$  gammas; vertical intensity  $+50$  gammas; and inclination  $-0.6$  (see table 2).

Three-hourly *K*-indices, indicative of geomagnetic activity, were assigned from the Eschenhagen traces and transmitted weekly to Washington, through the Australian Commonwealth Department of Air. As would be expected from its position in the sunspot-cycle, 1943 was a magnetically quiet year; indeed, only two periods of disturbance could be designated as "magnetic storms." Full descriptions of these disturbances were

transmitted to Washington, and table 4 gives their essential details. Magnetic data were supplied, on request, to the Australian and United States military units interested and also to the Australian Navy.

TABLE 3

SCALE-VALUES OF MAGNETOGRAPHS, WATHEROO MAGNETIC OBSERVATORY, 1943

MONTH	SCALE-VALUES IN $\gamma/\text{MM}$			
	ESCHENHAGEN		LA COUR	
	<i>H</i> (reduced to base- line)	<i>Z</i> (means of daily values)	<i>H</i>	<i>Z</i>
January	2.43	3.27	4.56	3.23
February	2.42	3.29	4.52	3.31
March ..	2.41	3.30	4.66	3.06
April ..	2.41	3.33	4.41	3.39
May	2.42	3.18	4.57	3.94
June	2.42	3.18	4.56	4.10
July ..	2.43	3.22	5.08	4.46
August	2.41	3.14	4.70	3.76
September	2.41	3.04	4.73	..
October	2.42	3.04	4.87	3.54
November	2.42	3.11	4.68	3.42
December.	2.42	3.17	4.67	3.39

TABLE 4

DETAILS OF MAGNETIC DISTURBANCES RECORDED AT THE WATHEROO MAGNETIC OBSERVATORY DURING 1943

DATE	RANGES		
	<i>H</i> ( $\gamma$ )	<i>D</i> ( $^{\circ}$ )	<i>Z</i> ( $\gamma$ )
August 7-9 ..	124	20	124
August 28-September 1	140	25	173

Continuous registration of earth-potentials, over a system of electrodes described in previous reports, was continued. Loss of trace through instrumental causes was quite small; the Weston Standard cell was replaced in August 1943. Electrode contact-resistance tests were made during September 1943. Scalings and reductions were brought up to

date and graphs of diurnal variation over the four lines show consistent results. The conducting lines have been patrolled regularly and defects repaired immediately after discovery.

Air-potentials were continuously recorded throughout the year, hourly values scaled, and monthly mean hourly values deduced. The ionium-collector used in the recording apparatus was compared with the Observatory standard in January 1944. Standardiza-

tions made as in previous years. Occasional failure of the hourly zero-relay led, in September 1943, to the installation of a Dunco locking relay, since which time no failure has occurred. Adjustments to the optical system resulted in improved traces. The presence of smoke in the air, already mentioned as affecting the potential-gradient records, also affected the conductivity traces, greatly reducing the number of days usable in the monthly tabulations. Minor repairs and ad-

TABLE 5

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
WATHEROO MAGNETIC OBSERVATORY, 1943

MONTH	POTENTIAL-GRADIENT			AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
	No. selected days	Reduction-factor	Value* (v/m)	No. selected days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+/\lambda_-)$
January.....	14	....	104.9	9	1.40	1.23	2.63	1.14
February.....	12	...	103.0	11	1.74	1.62	3.36	1.08
March.....	10	....	95.4	9	1.82	1.58	3.40	1.15
April.....	18	....	81.2	17	2.12	1.84	3.96	1.15
May.....	20	1.06	74.4	23	2.17	1.94	4.11	1.12
June.....	14	....	75.5	23	2.38	2.01	4.39	1.18
July.....	22	....	79.5	23	2.02	1.76	3.78	1.15
August.....	17	....	102.1	22	1.93	1.69	3.62	1.14
September.....	19	....	92.2	17	1.62	1.52	3.14	1.07
October.....	20	....	100.9	24	1.50	1.24	2.74	1.21
November.....	19	....	93.2	23	1.55	1.44	2.99	1.08
December.....	23	....	102.5	20	1.43	1.25	2.68	1.14
Totals and means.....	208	1.06	92.1	221	1.81	1.59	3.40	1.13

\*Using reduction-factor 1.10.

tion-observations, using the stretched-wire method and leak-free technique, were made in May 1943 and January 1944, to convert the values as recorded in volts to volts per meter. Table 5 gives the monthly mean air-potentials for 1943, using a reduction-factor of 1.10. Weekly calibrations of the recording electrometer were made as in previous years. Many of the daily records were vitiated by smoke from bush-fires; this was particularly troublesome during January and February 1944, owing to the absence of rain.

Positive and negative air-conductivities were continuously recorded and weekly calibra-

adjustments of the apparatus were made as required, and the scalings and reductions are current. Table 5 gives the monthly mean values of positive and negative conductivities, their sums and ratios.

The automatic multifrequency ionospheric recording apparatus was in practically continuous operation. The only breaks in registration were due to maintenance, calibration, and some minor repairs and adjustments necessary in the apparatus from time to time. Some breakages in the antenna systems during high winds were promptly repaired. Daily reports of ionospheric disturbances were

transmitted to Mount Stromlo through the Department of Air and copies of monthly mean hourly values have been sent to the Department of Air, the Radio Research Board, the Australian Navy, and Washington. Copies of the monthly tabulations were supplied to the Radio Propagation Committee of Australia and the National Bureau of Standards.

The use of the Hale spectrohelioscope, for the observation of activity in the chromosphere likely to give rise to magnetic and ionospheric disturbances, was limited for a portion of the report-year by reason of the small staff and the pressure of other more vital work. Daily watches were resumed, however, in February 1944.

The full program of meteorological observation and automatic recording was maintained. Coded reports of weather were prepared and transmitted thrice daily to the forecasting station of the Royal Australian Air Force in Perth, and monthly summaries of meteorological data supplied to the Commonwealth Weather Bureau, Melbourne. A daily journal of weather was kept. The reduction of the meteorological data, which was in arrears at the end of the last report-year, is now current. A feature of the weather prevailing during this report-year was the unusually dry summer of 1943-1944. Apart from a thunderstorm early in December 1943, little rain fell between October 11, 1943, and May 18, 1944. January 1944 was an exceptionally hot month; there were 12 days on which the temperature exceeded 100° F, the maximum on January 29 reaching 113°7, the highest for 25 years; on 7 nights the minimum temperature was over 70° F, the highest minimum (on January 17) being 81°7. The average temperature for January 1944 was 79°5. Table 6 shows the monthly rainfall at the Observatory during 1943.

Owing to the impossibility of obtaining manual labor during the greater part of the report-year, only general maintenance and urgent repairs to buildings and equipment could be done. The road from the Observatory to Watheroo was regraveled by Army units during October 1943.

W. C. Parkinson continued as Observer-in-Charge and W. D. Parkinson as part-time Junior Observer. The services of one technical assistant, one clerk, and a cook were made available by the Royal Australian Air Force as during the previous year. Two mechanics are regularly employed, although one (McCall) was absent because of sickness during May and June. A workman was made available through the National Service Office early in May, and he has been regularly employed since.

TABLE 6  
RAINFALL AT WATHEROO MAGNETIC OBSERVATORY  
DURING 1943

Month	Monthly total (in.)	No. days	Average for 26 years (in.)
January	1.15	3	0.37
February	0.65	6	0.54
March	1.74	6	1.06
April	0.92	10	0.92
May	1.74	8	2.19
June	3.64	13	3.38
July	1.22	12	2.85
August . .	1.37	10	2.17
September . .	1.19	14	1.27
October . .	0.48	5	0.82
November . .	0.04	2	0.30
December	0.96	4	0.41
Totals	15.10	93	16.28

As in previous years, the Observatory has had the helpful cooperation of various government departments. Grateful acknowledgment is made of the assistance of the Commonwealth Department of Trade and Customs for according free entry to supplies and equipment, to the Department of Air for the safe transmission of records and data to Washington and also for assistance in personnel matters (in the latter regard the Signals Branch of the Royal Australian Air Force, Western Area Headquarters, has been most sympathetic and helpful), and to the Council for Scientific and Industrial Research for receiving and forwarding shipments from Washington.

That practically the full program of the Observatory was maintained and an increasing quantity of current scientific data was made available to the services, departments, and investigators is a tribute to the sustained and concentrated efforts of the small Observatory staff, who have labored cheerfully and efficiently.

*Huancayo Magnetic Observatory.* The Huancayo Magnetic Observatory is situated about  $8\frac{1}{2}$  miles almost due west of the town of Huancayo in central Peru, at an altitude

insuring proper control of instrumental operation.

Two separate and complete three-element magnetographs were kept in operation continuously: an Eschenhagen and a rapid-run la Cour, and in addition a low-sensitivity la Cour *H*-variometer recorded on the Eschenhagen trace. Base-lines for the Eschenhagen were determined weekly by absolute observations made with magnetometer and earth-inductor. Scale-value deflections for the Eschenhagen variometers were made by the

TABLE 7

## SCALE-VALUES OF MAGNETOGRAPHS, HUANCAYO MAGNETIC OBSERVATORY, 1943

MONTH	ESCHENHAGEN			LA COUR	
	D ('/mm)	H (reduced to base- line) (γ/mm)	Z (means of daily values) (γ/mm)	H (γ/mm)	Z (γ/mm)
January .....	0.990	1.99	4.14	6.12	7.33
February .....	0.990	2.00	4.18	6.14	7.54
March .....	0.990	1.99	4.28	6.10	7.25
April .....	0.987	1.98	4.17	6.26	7.25
May .....	0.992	2.00	4.05*	6.28	7.16
June .....	0.984	1.97	3.79	6.19	7.26
July .....	0.990	1.98	3.93	6.20	7.48
August .....	0.985	1.97	4.00	6.01	7.76
September .....	0.988	1.99	4.05	6.22	9.01
October .....	0.989	1.97	4.05*	6.31	8.72
November .....	0.989	1.97	4.05*	6.13	9.12
December .....	0.989	1.97	4.13	6.19	7.62

\*Mean value over several base-line shifts.

of 11,000 feet (3350 meters) above sea-level. Its latitude is  $12^{\circ} 02'7$  south and its longitude is  $75^{\circ} 20'4$  west of Greenwich.

Traces from continuously operating, automatically recording apparatus are the source of practically all the data issued by the Observatory, and regular control- and check-observations assure their validity. Time-marks on the traces and a number of control-operations on the instruments are automatically effected by a master-clock and program-machine, which are frequently checked by radio time-signals. All the photographically recorded traces are developed daily, thereby

Helmholtz coil method weekly for the *H*- and *D*-records and three times a week for the *Z*-record; monthly scale-value deflections for the la Cour records were made by the same method. The resulting scale-values are given in table 7.

Magnetic character and *K*-index reports were made weekly by radio broadcast, and magnetic storms were reported monthly.

The preliminary values for the annual changes in the magnetic elements from 1942.5 to 1943.5 deduced from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning

east declination and north inclination as positive, are: declination  $-5.3$ ; horizontal intensity  $-38$  gammas; vertical intensity  $-10$  gammas; inclination  $-1.0$  (see table 2).

As in other years, the potential-gradient and the conductivity of the air were recorded continuously. Weekly calibration-observations were made for the instruments, and quarterly observations made on a near-by standardization-plot to determine the reduction-factor for the recorded potential-gradient values.

temperature for the year was  $24.5^{\circ}\text{C}$  in November 1943, and the maximum monthly mean was  $20.05^{\circ}\text{C}$  in October. The minimum temperature was  $-8.6^{\circ}\text{C}$  in June 1944, and the monthly mean minimum was  $-1.42^{\circ}\text{C}$ , also in June (this is an all-time monthly low for the 22 years).

Table 9 summarizes rainfall for each month of 1943 and the corresponding 22-year average for mean maximum temperature and mean minimum temperature.

TABLE 8

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
HUANCAYO MAGNETIC OBSERVATORY, 1943

MONTH	NO SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-1}$ ESU			
		Reduction-factor	Value* (v/m)	$\lambda_+$	$\lambda$	$(\lambda_+ + \lambda_-)$	$(\lambda_+/\lambda_-)$
January	2		63.4	3.68	3.65	7.33	1.01
February	1		50.4	3.92	3.64	7.56	1.08
March..	1	1.14	53.1	4.29	4.01	8.30	1.07
April..	8		54.5	3.98	3.92	7.90	1.02
May	4		49.0	4.12	4.32	8.44	0.95
June .	9	1.20	50.8	4.25	4.53	8.78	0.94
July....	9		51.0	5.16	5.39	10.55	0.96
August..	3	1.16	52.0	4.27	4.58	8.85	0.93
September ..	4		50.2	3.90	4.00	7.90	0.98
October	2		51.9	4.18	4.14	8.32	1.01
November	2	1.15	39.9	5.13	5.72	10.85	0.90
December	3		46.9	4.25	4.44	8.69	0.96
Totals and means	48	1.16	51.1	4.26	4.36	8.62	0.98

\*Using reduction-factor 1.15.

The preliminary values of the atmospheric-electric results for 1943 are given in table 8.

Nuclei-counts were also made daily at a point near the meteorological shelter at the time of the morning (08<sup>h</sup>, 75° west meridian mean time) meteorological observations, which were continued in the same form as in other years. Continuous recordings of barometric pressure, air-temperature, humidity, velocity and direction of wind, and hours of sunshine were made. The rainfall was measured daily, and the total for the year July 1, 1943 to June 30, 1944 was 32.91 inches, well above the 22-year average of 29.07 inches. The maximum

Continuous records of the earth-potentials were made between pairs of north-south and east-west earthed electrodes on two separate pampas in the vicinity of the Observatory. Only minor recording difficulties were encountered, but there was some interruption of recording caused by the pulling down of the transmission-lines from the electrodes.

The automatic multifrequency ionospheric recorder operated continuously throughout the year with only occasional loss of trace due to functional failure, although the equipment is showing the wear of seven years of continuous operation. The fixed-frequency unit,

recording on the same trace, also continued to function at 4800 kc/sec. Scaling and reduction of all data were kept current, each month's results going forward by air-express within the first few days after the end of the month. Three new masts were erected for the long antenna of the multifrequency-unit in the early part of 1944.

CIW model-C cosmic-ray meter 2 recorded the changes in cosmic-ray radiation.

Daily observations of the Sun with the Hale spectrohelioscope were made when conditions

opportunity to study changes in the ionosphere. The ionospheric recorder was operated at double normal speed for the 6 hours which contained the time of eclipse-period on 3 days before the eclipse, on the day of the eclipse, and on 3 days after the eclipse, thus giving excellent control-data. A careful analysis was made of the data obtained, and a joint report by the members of the staff prepared. During the eclipse, special recordings of potential-gradient and conductivity and observations of radio field-intensities and of

TABLE 9

MONTHLY MEAN METEOROLOGICAL ELEMENTS, HUANCAYO MAGNETIC OBSERVATORY, 1943, AND CORRESPONDING 22-YEAR MONTHLY MEANS, 1922-1943

MONTH	TOTAL RAINFALL		MAXIMUM TEMPERATURES		MINIMUM TEMPERATURES	
	1943 (in.)	22 years (in.)	1943 (°C)	22 years (°C)	1943 (°C)	22 years (°C)
January.....	4.23	4.86	18.17	18.69	6.34	7.01
February.....	7.32	4.23	17.28	18.29	6.94	7.00
March.....	3.74	4.42	17.33	18.22	5.77	6.49
April.....	0.99	2.07	18.82	18.88	4.05	5.04
May.....	0.96	1.17	18.45	19.36	1.96	3.06
June.....	0.57	0.42	17.62	19.00	1.54	1.90
July.....	0.47	0.31	17.90	18.92	-0.05	0.71
August.....	1.02	0.71	19.07	19.54	1.63	2.63
September.....	2.18	2.10	19.03	19.60	4.96	5.27
October.....	3.45	2.47	20.05	20.20	5.95	5.80
November.....	1.67	2.82	19.82	20.55	5.45	6.02
December.....	3.08	3.50	18.84	19.74	5.73	6.42

permitted in a total of 56 per cent of the scheduled observational periods, but activity of the flare-type was noted only three times.

The two Wenner horizontal-component and the Benioff vertical-component seismographs operated continuously, except for 24 days when the Benioff was not operated because of lack of photographic paper. Forty-five seismic disturbances were reported by radio during the year. F. P. Ulrich, of the United States Coast and Geodetic Survey, was at the Observatory for four days in April and assisted in a thorough check and readjustment of all three instruments.

A solar eclipse on January 25, 1944, 88 per cent total at the Observatory, provided an

nuclei-counts were also made. Small variations in these observations during the time of the eclipse showed correlation with the change in the solar light.

Joel B. Campbell, of the United States Coast and Geodetic Survey, was a visitor at the Observatory from May 27 to June 6, 1944. He was accompanied by representatives from the Peruvian Army and Navy. During the visit a magnetic comparison was made between the Observatory standard magnetometer 10 and field-magnetometer CIW 28, which was being used by Mr. Campbell in his field-work. During three weeks following this work, the Observer-in-Charge accompanied Mr. Campbell, Commander O. L.

Rivera, and Colonel Pedro A. Delgado on a field-trip to Chiclayo, Yurimaguas, Iquitos, Pucallpa, and Huanuco.

The scaling and reduction of data were kept current, and all instrumental equipment was kept in repair and efficient operation. Meteorological data were supplied regularly at the end of each month to the local military authorities in Huancayo and to the Dirección General de Comunicaciones y Meteorología Aeronáutico of the Peruvian Government. Meteorological data and magnetic data were also supplied to other interested persons and institutions.

Improvements to buildings included enlarging of the small storage-shed near the ionospheric laboratory to serve as a temporary ionospheric shop and laboratory after beginning construction, in May 1944, of the new ionospheric and field-intensity building.

No change in scientific personnel has taken place during the report-year. Paul G. Ledig continued as Observer-in-Charge, and Mark W. Jones, Albert A. Giesecke, Jr., and E. J. Chernosky as resident observers. Clerical assistants T. Astete, A. Macha, and V. Murga served faithfully. Macha resigned in early June 1944, to accept a scholarship in aviation mechanics in the United States. He was replaced by Elias Melgar. The hearty cooperation of these men made possible the satisfactory completion of the year's work.

Grateful acknowledgment is made of the generous assistance of the United States Embassy in obtaining free entry of equipment and supplies for the Observatory, and of the kindness of the Peruvian Government in granting this privilege. The kindness and helpfulness of the Peruvian people, both in official stations and in private life, were also factors in the progress of the Observatory.

*College Observatory, Alaska.* The College Observatory is located at the University of Alaska in the zone of maximum auroral activity, about 5 miles by road west of Fairbanks, in latitude  $64^{\circ} 51' 4$  north, longitude  $147^{\circ} 49' 3$  west, at about 381 meters (1250 feet) above sea-level.

During the year ended June 30, 1944, continuous measurement was made of the follow-

ing phenomena: (a) heights and densities of the ionospheric layers; (b) direction, horizontal and vertical intensity of the Earth's magnetic field; (c) electric field-strength from several selected high-frequency radio stations in the United States, England, Germany, and Japan; (d) rate of change of the horizontal component of the Earth's magnetic field; (e) intensity and duration of zenith aurora, as light and weather conditions permitted, from September through March; (f) direction of arrival of high-frequency radio signals from March 6, 1944. Observations and measurements for control of records were undertaken at intervals arranged to provide adequate standardization of the continuous records.

During the year the *H*-fluxmeter was moved from the old location to the signal-intensity laboratory. The auroral camera was relocated near the magnetograph-buildings and improved timing- and density-controls were added. A new set of cams was calculated and installed on the ionospheric equipment. Expressions for standardization of the signal-intensity records in terms of absolute field-strength were developed for the first time since the work was begun, in May 1941. The Z-variometer was adjusted so as to avoid shifts of base-line. Improved lighting was installed in the offices.

The Navy type DAB-3 direction-finder was installed and placed in operation. Supervision of the construction of the building and facilities for the direction-finder was undertaken. Leases for the site for direction-finder work were drawn and completed. Assistance to the Cold Weather Test Section of the Army Air Corps was rendered in measurement of field-strength laid down by various types of aircraft transmitters. Assistance was given the United States Coast and Geodetic Survey in general supervision of the seismic program at the University of Alaska. Some aid was given the Signal Corps in prediction of disturbance-periods of radio transmission for use at Adak, Anchorage, Fairbanks, Nome, and Seattle; like information was furnished to the Federal Communications Commission, the Civil Aeronautics Authority, and others until the inauguration of the regular program.

from Washington. Cooperation with the Army Air Corps enabled one lost plane to be located by direction-finder measurements and to make a safe landing.

Conferences were held with six local offices of the services and governmental bureaus to discuss conditions of radio propagation peculiar to the Arctic. A series of seminars kept the staff and interested persons acquainted with developments of the Observatory's program. Many reports on, and abstracts of, investigations conducted were prepared.

The preliminary mean values of the magnetic elements for the year 1943, as deduced from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination  $+29^{\circ} 50' 1$ ; inclination  $+77^{\circ} 12' 2$ ; horizontal intensity 12,572; vertical intensity  $+55,350$ .

Developments include transfer of the signal-intensity and ionospheric work from a research to an operational basis and the addition of the direction-finder program.

It was shown that the Arctic-type fade-out of radio signals is different from that falling under description of the Dellingler effect, and that it is probably the result of ionization by charged particles deflected toward the pole in the Earth's magnetic field. This confirms the work of Appleton and Builder in Norway some years ago.

Further confirmation of quasi-longitudinal type of radio wave-propagation in these latitudes was demonstrated, thus verifying the Appleton and Builder theory of magneto-ionic double refraction.

An effect has been described which indicates that high-frequency radio wave-propagation in these latitudes is constrained to approach a north-south line of arrival with increasing magnetic activity. Need for continuation of ionospheric work in high latitudes has been thoroughly demonstrated, as well as need for theoretical attack on processes of formation of the sporadic *E*-layer ionization.

S. L. Seaton continued as Observer-in-Charge; he was ably assisted by members of the temporary staff. The United States Army

Air Corps cooperated by part-time assignment of two assistants.

Grateful acknowledgment is made of the close cooperation of the President and Board of Regents of the University of Alaska in material aid and accommodations, which made for the success of the Observatory's continued program, and of the collaboration of the United States Army Engineers.

#### COOPERATION WITH OTHER OBSERVATORIES

*Cheltenham Magnetic Observatory, United States.* The cooperative program with the Cheltenham Observatory of the United States Coast and Geodetic Survey was continued, using CIW instruments for absolute standards in horizontal intensity and inclination. Automatic daily records of cosmic-ray intensity were continued with the CIW precision meter, through the courtesy of Observer-in-Charge J. Hershberger. Associate Magnetic Observer J. B. Campbell of the United States Coast and Geodetic Survey compared CIW magnetometer 28 with the standard magnetic equipment at Huancayo and also with sine-galvanometer 1 subsequently at Cheltenham, thus obtaining another control on our absolute standards at Huancayo.

*Tucson Magnetic Observatory, United States.* Through cooperation with the United States Coast and Geodetic Survey, registrations of atmospheric potential-gradient and of positive and negative air-conductivities were obtained, with the assistance of Observer-in-Charge J. H. Nelson. Table 10 summarizes the monthly and annual values of the atmospheric elements as computed by Mrs. G. Dewey, of the Observatory's staff. The observed value on June 21 of the reduction-factor for potential-gradient was 1.26, which is in good agreement with the station-mean of 1.24—the value used in table 10.

*Apia Observatory, Western Samoa.* In the geomagnetic program, CIW magnetometer 9 and CIW Schulze earth-inductor 2 were used for absolute observations. The source of the discrepancies in base-line observations for horizontal intensity was discovered, and satisfactory values have been adopted for the

period since 1937. *K*-indices were scaled for May 1941 to April 1944.

*Hermanus Magnetic Observatory, South Africa.* Dr. A. Ogg continued the use of CIW magnetometer-inductor 17 for absolute observations. Complete *K*-indices were received. The magnetic reductions for all days of the year 1943 were completed and reported.

*Godhavn Observatory, Greenland.* K. Thiesen continued the magnetic and cosmic-ray

of personnel. At the direction of Governor E. Brun of Greenland, and with the authorization of the Danish Minister at Washington, D. C., Mr. Thiesen again came from Godhavn to the Ivigtut Observatory for the period July 1-20, 1943, in order to maintain adequate control of the magnetic registrations. *K*-indices of geomagnetic activity were reported weekly through the cooperation of the United States Army Communication Services.

TABLE 10  
PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
TUCSON MAGNETIC OBSERVATORY, 1943

MONTH	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
	No. selected days	Value (v/m)	All complete days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January	19	61.6	29	2.36	2.20	4.56	1.07
February	23	53.9	28	2.51	2.32	4.83	1.08
March	15	48.6	27	2.50	2.36	4.86	1.06
April	19	50.2	29	2.58	2.48	5.06	1.04
May	19	50.6	31	2.52	2.50	5.02	1.01
June	13	53.7	29	2.53	2.51	5.04	1.01
July	17	49.0	24	2.31	2.15	4.46	1.07
August	11	58.0	25	2.36	2.20	4.56	1.07
September	17	47.3	26	2.56	2.37	4.93	1.08
October	23	51.5	27	2.71	2.47	5.18	1.10
November	23	48.3	28	2.46	2.40	4.86	1.02
December	21	58.0	21	2.23	2.04	4.27	1.09
Totals and means	220	52.6	324	2.47	2.33	4.80	1.06

programs. *K*-indices and magnetic reductions were received currently through the courtesy of the Secretary of State, Washington, D. C.

*Ivigtut Magnetic Observatory, Greenland.* Despite the hardship entailed in the operation of a magnetic observatory under severe climatic conditions, since the Observatory must necessarily be located at some distance from the mine-workings, S. O. Corp, Manager of the Ivigtut Cryolite Mines, obtained complete magnetic records. The company generously donated facilities, electric power, and services

*Christchurch Observatory, New Zealand.* Director H. F. Baird continued the operation of the CIW cosmic-ray meter. *K*-indices were regularly supplied.

*Royal Alfred Observatory, Mauritius.* CIW marine-inductor 4 continued on loan for determination of inclination at the Royal Alfred Observatory.

*Teoloyucan Observatory, Mexico.* Dr. J. Gallo, Director of the National Astronomical Observatory of Mexico, continued operation of the CIW cosmic-ray meter.

## PUBLICATIONS ON THE "CARNEGIE" DATA

A total of ten volumes in the series "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under Command of Captain J. P. Ault" have now been prepared for offset printing; of these, seven have been published. The volumes are generally classified under Biology (5 volumes), Meteorology (2 volumes), Oceanography (2 volumes, of which one is in two parts, and a third still to be prepared), Chemistry (1 volume). It is

necessary to prepare a twelfth and final volume to include general miscellaneous results and reports bearing on oceanography and recommendations based on experience on the *Carnegie*, for the use of other organizations taking up general programs at sea along like lines.

Preparation of final master copies from the manuscripts for offset production was done by Mrs. R. M. Crow, and the illustrations were arranged by Hendrix.

## INSTRUMENT-SHOP

The work of the Instrument-Shop and the Cyclotron Shop during the report-year totaled approximately 36,000 man-hours, of which 6900 were on construction of the cyclotron and approximately 23,800 (including some 3650 overtime) were on six war contracts.

Much work of the main shop was devoted to making replacement parts for ionospheric apparatus at Watheroo, Huancayo, and College observatories. Minor repairs and modifications were made to the Gish-Hess ionization-chambers, to the control-

box for the sine-galvanometer at Cheltenham Magnetic Observatory, and to other instruments. The foundry, during ten days of operation, made 421 pounds of nonmagnetic brass castings and 400 pounds of lead castings.

Some 5300 man-hours were used for urgent necessary maintenance of buildings and grounds, construction of furniture and benches for the Cyclotron Building and of many storage-cabinets, packing of equipment for shipment, and provision for increased number of staff.

## MISCELLANEOUS ACTIVITIES

There was active participation in scientific meetings, conferences, and organizations by members of staff, of whom many served as officers and on special committees. So far as possible, contacts were maintained with geophysical organizations and geophysicists abroad and in the United States. A great portion of the Department's activities was absorbed in matters relating to aspects of the war effort and in conferences with cooperating observatories and organizations in the United States and Canada.

*Library.* There has been practically no

change in the international situation with regard to foreign scientific books and journals, from that outlined last year. The principal British scientific journals and some publications from the Union of Socialist Soviet Republics are received with more or less delay. Although the number of books and magazines\* emanating from Axis-dominated countries, reproduced with the permission of the Alien Property Custodian, was considerably extended, only a few of these reproductions were purchased, chiefly because of the diminishing number of contributions of interest in

connection with the researches of the Department. In domestic publications also, owing to the absorption of an ever-increasing number of investigators into activities bearing directly on the war, some falling off of major original contributions to terrestrial magnetism and electricity has been evident.

Despite these unfavorable conditions, the total of 487 accessions was somewhat greater than that for either of the two previous years. The total number of accessioned books and pamphlets on June 30, 1944 was 27,540. The practice of cataloguing all articles in current periodicals, as well as books, reprints, and other pamphlets, bearing on subjects under investigation at the Department was continued, facilitating reference to data otherwise not readily accessible.

The project of making available translations in English of outstanding contributions to the early history of geomagnetism, begun last year, was continued. Three additional contributions, provided with suitable introductions, were published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*; these are as follows: The letter of Georg Hartmann to Duke Albrecht of Prussia (1544); The shadow instrument, by Pedro Nunes (1537); letter of Gerhard Mercator of Rupelmonde to Antonius Perrenotus, Most Venerable Bishop of Arras (1546). We are indebted to Dr. J. de Sampaio Ferraz, of Rio de Janeiro, for the translation of the contribution of Pedro Nunes, as well as for a similar translation from sixteenth-century Portuguese of selections from the log-books of João de Castro, to be published later.

The Librarian continued as coeditor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, giving attention particularly to foreign contributions, preparation of notes, reviews of books and

reports, and annotated bibliographies of recent publications on cosmic and terrestrial magnetism and electricity.

The list of publications by members of the Department on December 31, 1943 showed a total of 2267. Reprints of these papers are distributed to a list of interested persons and institutions; because of urgent work connected with the war and of postal restrictions, complete distribution must be delayed until some future time.

As in the past, the facilities of the Library were made available to students and investigators from governmental bureaus and particularly to specialists concerned with the prosecution of the war. Interlibrary loans were continued with a number of libraries. Information on a large variety of subjects, some bearing only remotely on the work of the Department, was supplied in response to requests from various sources. Cordial relations were maintained with other libraries, particularly the Library of Congress.

Dove continued as Secretary to the Director and remained in charge of the general correspondence files of the Department and the storage and distribution of reprints. He typed many reports and manuscripts.

*Office administration.* The war work of the Department has occupied practically all the regular time and a considerable amount of overtime of the staff assigned to Administrative Assistant M. B. Smith. This included correspondence, placing of orders, accounting, and matters concerned with personnel. The large amount of work done would not have been possible without the efficient assistance of Moats, Miss Gottshall, Miss Dermody, and Dove, of the regular staff, and of the many temporary employees assigned to the Administrative Assistant.

The many details of wartime shipments, inventories, statements of time and costs

of work, and preparation of reports and manuscripts were completed by Capello, Secretary and Property-Clerk. Charts, diagrams, and illustrations for many special reports and publications were prepared by Hendrix, who with J. W. Green also did

a great amount of necessary photographic work and reproductions. Filing and arranging of field-records were done by Miss Balsam, who with Capello maintained the catalogues of photographs and films, and index-albums of prints.

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#### SPECIAL PUBLICATIONS

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## SPECIAL PROJECTS: TERRESTRIAL SCIENCES

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1943 to June 1944.* (For previous reports<sup>1</sup> see Year Books Nos. 32 to 42.)

Despite the continued assignment of interested personnel to war-research problems, good progress was made by several of the groups with whom the Carnegie Institution of Washington has been privileged to cooperate. The programs of Messrs. R. B. Brode, S. E. Forbush, Thomas H. Johnson, C. E. Nielsen, Wilson M. Powell, and M. S. Vallarta are in abeyance, but each one expects to resume his investigations as soon as conditions permit.

The operation of cosmic-ray meters at Cheltenham, Huancayo, Teoloyucan, Christchurch, and Godhavn was maintained almost without interruption by the collaborating agencies. The supplying of recording paper, replacing of batteries and parts, and filing and copying of records to make them promptly available for any current and future use were effected by the Department of Terrestrial Magnetism. The emergency continued those difficulties of obtaining materials, supplies, and shipping facilities, especially for the stations abroad, referred to in last year's report.

The groups at University of Chicago, California Institute of Technology, Fordham University, and New York University made progress as indicated in the appended reports. All these reports show worth-while developments and discussions as well as potentialities for future theoretical and statistical investigations and discoveries.

Grateful acknowledgment is made to the directors and members of organiza-

tions which continued their contributions and services to the program; these include the Danish Meteorological Institute, the National Astronomical Observatory of Mexico, the New Zealand Department of Scientific and Industrial Research, and the United States Coast and Geodetic Survey. The Consul-General of Denmark in New York and the United States Coast Guard were most helpful in connection with the forwarding of the necessary supplies for operation and maintenance of the observatory at Godhavn.

W. S. ADAMS

J. A. FLEMING, *Chairman*  
F. E. WRIGHT

### STATISTICAL INVESTIGATIONS OF COSMIC-RAY VARIATIONS AT DEPARTMENT OF TERRESTRIAL MAGNETISM

S. E. FORBUSH AND ISABELLE LANGE

*Instruments.* Operation of the Carnegie Institution's precision cosmic-ray meters was continued at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-1, John Hershberger in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, meter C-2, P. G. Ledig in charge; National Astronomical Observatory of Mexico at Teoloyucan (D. F., Mexico), meter C-4, Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, meter C-5, J. W. Beagley in charge; Godhavn (Greenland) Magnetic Observa-

<sup>1</sup> For statement on formation, purposes, and policies of the Committee see Year Book No. 38 (1938-1939), pp. 335-349.

tory of the Danish Meteorological Institute, meter C-6, K. Thiesen in charge.

*Reduction of data.* Scalings and tabulations of hourly values of cosmic-ray ionization, bursts, and barometric pressure could not be kept current owing to pressure of war work.

The full-time engagement of Mr. Forbush and Miss Lange on war research permitted only routine handling of records and making copies of data received for distribution to interested investigators.

#### COSMIC-RAY WORK AT FORDHAM UNIVERSITY

VICTOR F. HESS

*A study of the ionization of the atmosphere by cosmic and terrestrial radiation.* In 1941 the author suggested methods which make it possible to determine simultaneously the residual ionization and the effect of cosmic rays and of local gamma rays from the ground, and to separate these components of total ionization.

The apparatus, designed by O. H. Gish and K. L. Sherman, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, and constructed by that Department, was used by the author in preliminary measurements in and around New York in the summer and autumn of 1943.

The ionization over water (on a wooden pier 80 meters from the shore and on a yacht offshore, Long Island Sound), where gamma rays from the ground were absent, was found to vary between 1.7 and 2.7 ion-pairs per cc at normal pressure and temperature ( $I$ ); the average was 2.36  $I$ . Individual daily mean values between July and October from 09<sup>h</sup> to 16<sup>h</sup> were 1.74, 2.00, 2.73, 2.51, 2.60, 2.71, 2.56, 1.87, 2.16  $I$  (chambers filled with pure, dry, filtered nitrogen, at normal pressure and temperature). The total variation of about one  $I$ .

might be attributed either to changes of "air-radiation" (gamma rays from the radioactive products in the atmosphere), or to the cosmic radiation, or to both.

Measurements over land (in gardens) gave an average of 4.9  $I$ . Subtracting 2.36  $I$  (cosmic plus air-radiation), one gets at least 2.5  $I$  for gamma rays from the ground at all locations where the ground consisted of humus and was covered with grass. This is considerably more than one would expect if the most recent values for the radium-, thorium-, and potassium-content of sedimentary rocks are adopted (1.1  $I$ ). In addition it was found that the variation of the ionization over land was twice as great as over water.

The apparatus was overhauled and improved in the shop of the Department of Terrestrial Magnetism during the winter and will be used for further experiments in the summer and fall of 1944.

#### COSMIC-RAY INVESTIGATIONS AT NEW YORK UNIVERSITY

S. A. KORFF

In spite of the pressure of urgent war work, it has been found possible to devote a certain amount of effort to cosmic-ray studies. One investigation started last year was completed and another is still in progress. During the period July 1, 1943 to June 30, 1944, the following researches were made, aided in part by funds supplied through the Carnegie Institution of Washington:

*Study of the quenching mechanism in self-quenching counters.* A theory describing the quenching mechanism in self-quenching counters was evolved and was found to be supported by experimental tests. It has been known for some time that the addition of almost any organic vapor to the gas contained in a Geiger-Mueller counter causes the discharge in

these counters to extinguish itself, and therefore such "self-quenching" counters may be operated without the supplementary resistances or vacuum-tube quenching circuits used with the non-self-quenching counters. The mode of operation of the organic vapor has been somewhat obscure. In an effort to produce better counters for cosmic-ray work, the mechanism was studied in detail.

Briefly, the theory suggests that the quenching action is due to two phenomena, produced by the organic molecules. The first effect occurs because the ionization-potential of the organic quenching constituent is lower than that of the inert gases used. Consequently, electron-transfer takes place, and the positive ions reaching the cylinder are entirely those of the organic molecules. Secondly, these organic ions upon neutralization predissociate rather than radiate, because in the complex molecule the energy in the molecular bond is less than that involved in the electronic transitions. Since the molecules do not radiate, no photoelectrons are formed, and with the supply of secondary electrons thus cut off, the discharge ceases and the counter is said to be quenched. Experimental tests lent support to this hypothesis.

*A new measurement of the ratio of mesotron-mass to lifetime.* A mathematical analysis of the correlation between the observed fluctuation in the cosmic-ray intensity at sea-level and the meteorological variables throughout the atmosphere has been made. This analysis, combined with the experimental observations of the quantities in question, yields a new value for the ratio of the mesotron-mass to lifetime. The analysis assumes that the mesotrons are largely produced at high elevations and takes account of the loss in mesotron-intensity due both to decay and to ionization, as the producing layer is moved up and down by the changing air-masses

below it. Previous analyses had all made simplifying assumptions which were found to be open to criticism in that they neglected the interdependence of the two modes of loss of energy. The actual correlations made with the aid of this analysis by comparing observed cosmic-ray data with information on weather at various elevations obtained by radiosonde were found to be more significant than were the correlations of the same data when computed according to the older methods in common use. For example, the customary procedures in computing coefficients of pressure and external temperature can be improved and rendered more accurate by calculating a single "air-mass" coefficient. The ratio having once been determined, the correlations can also be employed to give additional information regarding the behavior and the nature of the air-masses by observing the changes in the cosmic-ray intensity at sea-level. An improved cosmic-ray telescope is under construction to make possible the obtaining of further data.

*Personnel.* It is a pleasure to acknowledge the cooperation received from several persons. Professor R. D. Present collaborated in the development of the theory of self-quenching counters. Messrs. Kenneth Kupferberg and F. Reines and Dr. B. Hamermesh have participated in the mathematical analysis of the mesotron-intensity and its dependence on meteorology.

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COSMIC-RAY STUDIES AT CALIFORNIA  
INSTITUTE OF TECHNOLOGY

ROBERT A. MILLIKAN, H. VICTOR NEHER, AND  
WILLIAM H. PICKERING

This year, July 1, 1943 to June 30, 1944, as in the year preceding, we have been prevented by our war responsibilities from making the much-needed and long-planned measurements, with a vertically arranged pair of counters, at and near the predicted latitude of first vertical entrance of the helium-annihilation rays, and from checking again, by similar measurements, the latitude of first vertical entrance of carbon-annihilation rays. Nevertheless, we have been able to make a careful study and analysis of data, as yet unpublished, taken in the summer of 1940 by means of high-altitude electroscope-flights. Accordingly we are now able to add some new facts and some new elements of interpretation, as follows: (1) We find definite evidence that a new band of rays, which we interpret as helium-annihilation rays, does come in vertically at about the predicted latitude. (2) We present a discussion of the possible composite character of the so-called silicon-annihilation band and of the so-called oxygen-annihilation band. (3) We bring forward an explanation of the cause of the large and already reported variability in the cosmic-ray intensities found in high-altitude electroscope-flights at Bismarck, Omaha, and Oklahoma City. (4) We make a new and more accurate

determination of the value of the field-sensitive and the non-field-sensitive components of the incoming cosmic rays.

1. *Evidence for helium-annihilation rays entering between magnetic latitudes 51°3 and 56° N.* That a new band of rays that has the low penetrating power of the helium-annihilation rays has come in between the curves for Omaha and Bismarck (that is, between magnetic latitudes 51°3 north and 56° north) is shown in figure 2 by the difference between the two curves at the top, and their complete coincidence at all levels lower down in the atmosphere than about 1.8 meters of water.

On the other hand, the difference between the curves for Omaha and Oklahoma City is seen to extend down to low altitudes, for the reason, as we think, that there are no abundant atoms between carbon and helium, so that carbon-annihilation rays, three times as energetic as helium-annihilation rays (combined also with some smaller amounts of nitrogen- and oxygen-annihilation rays), keep the curves apart. Incidentally, we find indications (see table below) that the top of the curve for Omaha probably has a considerable ingredient of helium rays in it.

The curves of figure 2 furnish, then, some indirect evidence in support of the very much better direct evidence already reported (*Phys. Rev.*, vol. 63, p. 241, fig. 7, 1943) that, since there are no abundant atoms in interstellar space of weights between those of carbon and helium, there is indeed—as there should be on the basis of the atom-annihilation hypothesis—a flat plateau of constant vertically incoming cosmic-ray energy between, say, magnetic latitudes 44° and 54° north. At any rate, figure 2 is not inconsistent with this prediction.

2. *The possible composite character of the silicon and the oxygen bands.* It is

desirable to call attention to one further characteristic of some of these five predicted cosmic-ray bands, namely, the so-called silicon-band, which we found in India between Agra (magnetic latitude  $17^{\circ}3$  north) and Peshawar (magnetic

$28.3$ ) is probably ten times more abundant in interstellar space than are any of the three closely adjacent elements aluminum (atomic weight 27.1), phosphorus (atomic weight 31), and sulphur (atomic weight 32), these are all so close to silicon in

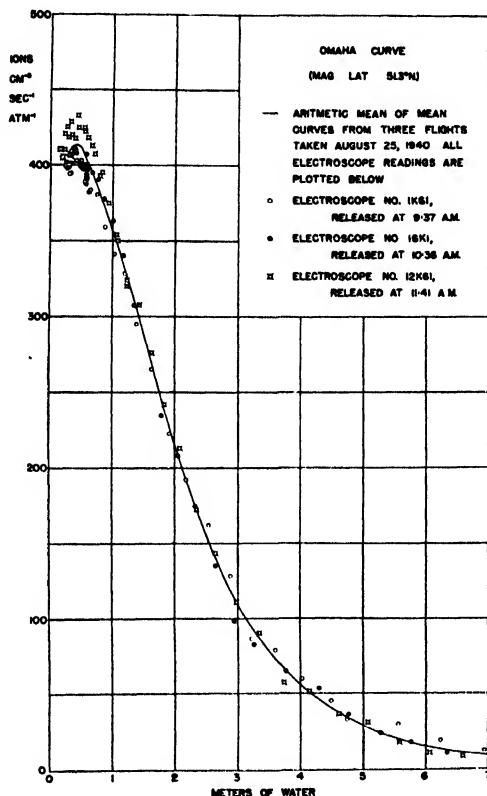


FIG. 1. Details showing consistency obtained in three successive flights in one day; similar consistency was shown between component curves making up each of five mean curves of figure 2 (flights from August 21 to September 3, 1940).

latitude  $25^{\circ}$  north), and the oxygen-band, which we found in Mexico (about magnetic latitude  $33^{\circ}$  north). Both these bands may have a composite character. For although, according to Bowen's measurements (Phys. Rev., vol. 61, p. 399, footnote 5, 1942), silicon (atomic weight

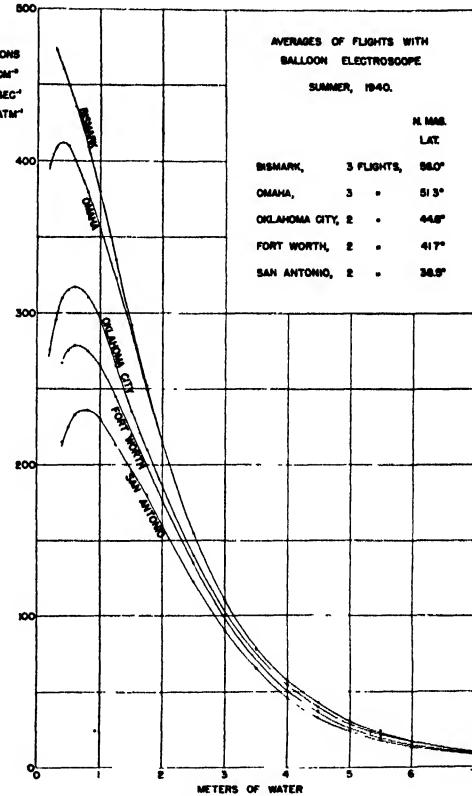


FIG. 2. Soft helium rays cause Bismarck-Omaha difference only at high altitudes; penetrating carbon rays cause difference between Oklahoma City and Omaha extending down to low altitudes.

weight that their annihilation rays would be quite inseparable by the type of tests we have so far made.

Hence, for simplicity we shall continue to designate this observed band of incoming rays the "silicon-band" without wishing to deny to it the possibility of

a composite structure. Indeed, P. Swings, who, with his collaborators, has recently made elaborate studies on the abundance of both atoms and molecules in interstellar space (*Astrophys. Jour.*, vol. 95, p. 270, 1942; see also *ibid.*, vol. 92, p. 292, 1942; *Astron. Soc. Pacific*, vol. 54, p. 3, 1942; *Jour. Roy. Astron. Soc. Canada*, vol. 35, p. 74, 1941), says, "It may safely be assumed that the atomic populations in interstellar space of hydrogen, oxygen, nitrogen, and carbon per cc are between 1 and  $10^{-3}$ ." These estimates of the actual interstellar abundance of these atoms are not out of harmony with Bowen's *measurements* of the *relative* interstellar abundance of atoms. From these Bowen finds (*loc. cit.*) the helium atom one-tenth as abundant as the hydrogen atom, and the atoms of carbon, nitrogen, oxygen, and silicon each about one-tenth as abundant as the atom of helium.

Swings also writes us that "the interstellar abundance of the carbon compound molecules  $\text{CH}$  and  $\text{CH}^+$  must be of the order  $10^{-6}$  per cc." In other words, the most abundant interstellar *molecules* would have only  $1/10,000$  of the abundance of the foregoing abundant atoms, carbon, oxygen, nitrogen, and silicon, so that so far as the origin of the "field-sensitive cosmic rays"<sup>1</sup> is concerned, no molecules and no atoms heavier than the atoms causing the silicon-band need to be considered at all. This introduces a very great simplification into the whole problem of origin.

The oxygen-band like the silicon-band

may have a bit of complexity about it, for, according to Bowen's table (*loc. cit.*), the neon atom has one-tenth the interstellar abundance of oxygen. Because of its weakness and closeness to oxygen (atomic numbers 10 and 8, respectively), we had no hope of separating the two effects and decided to designate the whole effect as the "oxygen-annihilation band."

3. *The variability in incoming cosmic-ray intensities.* From as careful a study as we have been able to make of the Lemaitre-Vallarta curves reproduced in figure 2 of an earlier paper (*Phys. Rev.*, vol. 61, p. 401, 1942; see also Lemaitre and Vallarta's original papers in *Phys. Rev.*, vol. 49, p. 719, and vol. 50, p. 503, 1936; and vol. 43, p. 87, 1933), supplemented by a little adjustment, especially in the case of the oxygen-band, because of our own observations shown in figure 4 in *Physical Review*, vol. 61, p. 403 (1942), and because of the evidence presented in *Physical Review*, vol. 63, pp. 239, 242 (1943) that off the west coast of South America the electronic energy necessary to get vertically through the resistance of the Earth's magnetic field at the equator is 13 billion electron-volts (bev) instead of the 15 bev assumed by Lemaitre and Vallarta (probably a correct assumption for computing incoming energies north of Pasadena), we have estimated in the accompanying table the critical mag-

CRITICAL MAGNETIC LATITUDES IN NORTH AMERICA  
FOR ENTRY OF COSMIC ANNIHILATION RAYS

ATOM	ENERGY (bev)	LATITUDE OF		
		First entry on western horizon	Full entry on eastern horizon	Vertical entry
He.....	1.88	51°	59°	54°
C.....	5.6	32	49	42
N.....	6.6	27	48	39.5
O.....	7.5	22	46	33.5

<sup>1</sup> We define non-field-sensitive cosmic rays as those at the magnetic equator in India when the measuring instrument that is carried to the top of the atmosphere is an electroscope. Field-sensitive rays are the *additional* rays that come in when the electroscope-measurements are carried out at successive latitudes between the equator and the pole.

netic latitudes for the entry of the cosmic annihilation rays as measured by electroscopes.

This table brings to light the bad overlapping of the various bands and the impossibility of unscrambling them, save in the case of the helium-band. But because of the wide difference in energy between helium and carbon, the former is able to appropriate to itself entirely all latitudes above  $51^{\circ}$ , so that, on the basis of the atom-annihilation hypothesis, if in going north new cosmic rays come in between  $51^{\circ}$  and  $59^{\circ}$ , they can only be helium-annihilation rays. In fact, as is shown in figure 2, there can be no uncertainty about the appearance of a new band of rays between Omaha and Bismarck, and a band so little penetrating, as helium-rays should be, that it cannot throw its influence down even to the 2-meter level, below which depth the curve for Bismarck is seen in figure 2, as stated above, to coincide completely with the curve for Omaha.

We have published on several occasions in recent years the discovery of large and, thus far, wholly inexplicable changes in incoming cosmic-ray intensities as measured by the electroscope-technique in the northern part of the United States.

Thus, in September 1937 we made good flights with electroscopes at Omaha to such heights as to get definitely over the maximum of ionization in our electroscopes. The value of this ionization at the top when reduced to standard air-density was 338 ions per cc. In 1938 we went to Omaha in winter (late December), repeated these experiments, and found a maximum ionization at the top of 364 ions per cc, an increase of nearly 8 per cent. The maximum ionization shown at the top in the flights of 1940 herewith reported (see figs.

1, 2) is 413 ions per cc, an increase over December 1938 of 13.4 per cent.

Again, the maximum which we obtained in Bismarck in the summer of 1938 was 374 ions per cc, whereas the maximum found in 1940 at Bismarck and reported in figure 2 was 485 ions per cc, or an increase over 1938 of 29.7 per cent.

Still further, our maximum obtained in Oklahoma City in the summer of 1938 was 280 ions per cc, whereas the maximum shown in the summer of 1940 (see fig. 2) is 319 ions per cc, an increase over 1938 of 14 per cent. Contrast the foregoing findings with the fact that in electroscope-flights at San Antonio in the summer of 1936 we got a maximum of 234 ions per cc, and that when we repeated these flights in 1940, we found (see fig. 2) precisely the same maximum as in 1936.

Also, not only was our maximum at Madras, India, in 1936 the same as in February 1940, but, as was shown in the report of our India work (Phys. Rev., vol. 61, p. 408, fig. 1, 1942), the two curves taken four years apart are everywhere indistinguishable.

In a word, whereas the cosmic rays coming in at Madras and at San Antonio seem to remain amazingly constant, in the northern part of the United States they show amazing fluctuations.

We seek the explanation of this strange behavior in the atom-annihilation hypothesis as follows: We assume for simplicity that the cosmic processes creating the cosmic rays cause an essentially constant incidence of all the five cosmic-ray bands on the Earth. According to Bowen, helium is ten times more abundant than carbon, nitrogen, oxygen, or silicon, and even from the standpoint of energy, if the probability of the transformation of the whole rest-mass into an electron-pair is the same for all atoms, the energy in the

helium-band is some 3.5 times that in the carbon-, nitrogen-, and oxygen-bands, and some 1.5 times that in the silicon-band.

Bismarck and Omaha both lie close to the southern edge of the polar cap of helium-annihilation rays, which we have computed as located for vertical-counter measurements at magnetic latitude  $54^{\circ}$  north, and for electroscope-measurements at between magnetic latitudes  $51^{\circ}$  north and  $59^{\circ}$  north. With even slight changes in the Earth's magnetism, this edge of the helium polar cap will move north or south, and, since the resistance to incoming electrons is very small in northern latitudes, the relative effect of changes in the Earth's magnetic field may be correspondingly large, depending upon the kind of cause that makes the change. In equatorial latitudes, where the resistance to incoming electrons is say eight times larger than at Bismarck or Omaha, the fluctuations in the Earth's magnetic field will have smaller influence, and no influence at all unless the point of observation is near the edge of one of the five polar caps corresponding to the latitude of entrance of one of the cosmic-ray bands.

In the present experiments, according to the table above, the helium-rays from the western horizon are already passing through the electroscope in the upper levels of the atmosphere, and a very little change in the Earth's magnetic field that would make the band move say  $2^{\circ}$  southward, according to Lemaitre-Vallarta curves, would throw the greater part of the energy of the helium-band into the top of the curve at Omaha. It is presumably actually there in these observations in which the curve for Omaha runs higher than we have observed it to do in any of our other trials there.

Oklahoma City is the only place, save Bismarck and Omaha, at which these

changes have been observed, and here they were in smaller amount. Oklahoma City is actually quite close to the computed latitude of entrance of the carbon-band. The reason for the high values of the curves for Bismarck, Omaha, and Oklahoma City in 1940 is that then the edge of the helium and carbon polar caps were farther south than at the time of previous readings. Furthermore, as the table shows, the width of the slope of the rise to a new plateau increases greatly for the more southerly bands. This is another reason why a small change in the Earth's magnetic field has little effect in the more southerly latitudes, but a large effect in the northerly ones.

4. *The field-sensitive component of the cosmic ray.* In view of the greater accuracy attained in these electroscope-measurements than in our preceding ones, we have computed from the new curves of figure 2, combined with the unchanged measurements at Madras (Phys. Rev., vol. 61, p. 397, figs. 1, 7, 8, 1942), that the field-sensitive component defined through these electroscope-readings is 65 per cent of all incoming cosmic-ray energy. All this is due to incoming charged particles. There is at present no way of finding what fraction of the non-field-sensitive component is due to charged particles and what to photons, though part of it is unquestionably due to the former.

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COSMIC-RAY RESEARCH AT THE UNIVERSITY  
OF CHICAGO

MARCEL SCHEIN

*Mountain experiments.* In the summer of 1943, cosmic-ray experiments were carried out on Mount Evans, Colorado. Since the beginning of 1943 the territory around Mount Evans has been occupied by the United States Army Air Forces. By special permission of General Lawson, commanding officer of Buckley Field, the expedition was allowed to stay at Camp Echo and to carry out cosmic-ray studies at Echo Lake and on top of Mount Evans. The very efficient assistance the expedition received from the United States Army greatly helped in carrying out an extensive program of cosmic-ray research.

Marcel Schein and J. Tabin measured the penetration and shower-production of cosmic-ray particles in the energy-range below  $2 \times 10^8$  electron-volts (e-v). It was found that many of these particles traversed three lead plates in succession without producing any showers in the lead. Hence these particles do not consist of electrons. If they were mesotrons or protons, however, their tracks in the cloud-chamber should exhibit a considerably heavier ionization than those of electrons. Since the majority of them show electronic tracks in the chamber, it is concluded that these particles must have a mass intermediate between that of an electron and that of a mesotron. The mass of the new particle can roughly be estimated at about 20 electronic masses. Furthermore, it is assumed that the new particle is unstable and disintegrates spontaneously into electrons and neutrinos. New experiments dealing with the problem of creating low-mass mesotrons artificially by high-energy photons are planned for the near future.

A series of experiments on the production of mesotrons in different materials

were carried out by J. Tabin on top of Mount Evans (14,200 feet) and at Echo Lake (10,600 feet). A production of single mesotrons by non-ionizing radiation was found to be present in paraffin, aluminum, iron, and lead. The cross-section of this process is nearly equal to the area of the corresponding atomic nucleus. It is therefore concluded that the creation of a mesotron is a nuclear process. The nature of the mesotron-producing radiation was investigated and it was found that most of the mesotrons on Mount Evans are produced by non-ionizing rays which are very absorbable in 1 cm of lead but are capable of penetrating as much as 60 cm of paraffin. This definitely indicates that in the lower atmosphere the mesotrons are produced by photons.

L. G. Lewis used a new method to investigate extensive atmospheric showers. The method consists in measuring the coincidences between cosmic-ray bursts which occur simultaneously in two unshielded ionization-chambers. R. E. Lapp proved that at sea-level these bursts are caused by the high-density regions of atmospheric showers traversing both ionization-chambers simultaneously. To explore this high-density part of the shower, the coincidences between bursts were measured as a function of chamber-separation. These experiments yielded a number of entirely new results. It was found that some of the showers covered the area of 100 m<sup>2</sup> with a minimum density of 6000 particles per m<sup>2</sup>. Such showers must originate from primaries having energies as high as  $10^{17}$  e-v, which represents the highest energy observed so far. In numerous cases showers were found with their cores (high-density regions) extending from 1 to 2 meters from the center of the shower. This is 30 times smaller than predicted by the theory for showers initiated by primary electrons. On the basis

of current theories, the presence of these very narrow showers can only be explained by assuming that they originate from secondary electrons or photons which are produced not too far above the point of observation. The mechanism by which such high-energy electrons and photons<sup>1</sup> could be produced, however, is not known in physics so far.

A search for mesotrons in extensive showers was made by A. Rogozinski. He found that the positive results obtained by previous investigators can be partly explained by the presence of collision-electrons in air produced by mesotrons.

*Balloon experiments in the stratosphere.* The multiple production of mesotrons in paraffin was studied in the high atmosphere by Marcel Schein, M. Iona, Jr., and J. Tabin. It was found that in a block of paraffin of 5-cm thickness multiple mesotrons are frequently produced by ionizing primaries (protons). This result is not in agreement with the predictions of a recently developed theory of the production of mesotrons by protons (Heitler, Hamilton, and Peng, 1943). According to this theory, the mesotrons should be created as singles in successive processes. Such a cascade-production of mesotrons does not give a sufficient number of multiple processes in a block of paraffin of 5-cm thickness.

For measuring the frequency of giant atmospheric showers in the stratosphere, a balloon-apparatus of large dimensions was constructed by P. Auger, A. Rogozinski, and Marcel Schein. Two groups of cosmic-ray counters were placed at a distance of 26 feet from each other, and the three-, four-, and fivefold coincidences were registered between five different counter-com-

binations. The results show that very few high-density showers of large extension are present in the stratosphere. Showers exhibiting a high particle-density have very small extension at high altitudes (50 cm from the center of the shower), a fact which shows that these showers are in the initial stages of their development. This is in good agreement with the results obtained by Lewis at Echo Lake, Colorado.

A general analysis of cosmic-ray phenomena in high altitudes was attempted by Marcel Schein. Using the data on multiple mesotron-production in the stratosphere, a separation of the mesotron-component from the proton-component was made possible. The curve obtained for the mesotron-intensity as a function of atmospheric pressure exhibits a maximum at a pressure of 5 cm of mercury. The primary protons entering the Earth's atmosphere are quickly absorbed by nuclear collisions in air, and as a result their intensity is very small in the lower atmosphere.

*Sea-level experiments.* The frequency of cosmic-ray bursts was measured by R. E. Lapp in a model-C meter shielded by different thicknesses of iron. The transition-curve of bursts has a pronounced maximum at a thickness of 12 cm of iron. Lapp found that a large fraction of the bursts registered below 12 cm of iron originates from atmospheric showers capable of traversing the iron shield. This was shown by putting a number of coincident counters at a distance of several meters from the chamber and then recording those events in which bursts in the ionization-chamber occur simultaneously with large air-showers discharging all the counter-tubes. The core of these showers contains high-energy electrons capable of penetrating the shield. This method was used for determining the penetration and the average energy of the electrons in the core of an air-shower.

<sup>1</sup> A possible mechanism for the production of such electrons would be the spontaneous decay of mesotrons with an extremely short mean life (lifetime less than  $10^{-9}$  second).

The results show that some of the showers at sea-level contain electrons of energies as high as  $10^{11}$  e-v.

K. Kingshill measured at sea-level the coincidences between bursts occurring simultaneously in two unshielded ionization-chambers. The results give a considerably smaller number of burst-coincidences at sea-level than at the altitude of 10,600 feet. The increase in the number of burst-coincidences with elevation is very much larger than the corresponding increase in the number of counter-coincidences found by N. Hilberry. This is due to the fact that by the method of counter-coincidences showers of a much smaller density are selected than by the method of coincident bursts.

*Theory of cosmic rays.* It is now well established that mesotrons moving through the Earth's atmosphere disintegrate spontaneously into electrons and neutral particles of unknown nature (probably neutrinos). The spectrum of the electrons arising from the disintegration of these mesotrons was calculated by H. E. Stanton. The theoretical spectrum of the electrons was determined for an altitude of 14,200 feet (Mount Evans) and the results were compared with the experimental data obtained by D. Hall on Mount Evans and by W. Hazen in California. The agreement between theory and experiment is satisfactory in both cases. It can therefore be concluded that the electrons in the lower atmosphere are secondaries of the mesotron.

The lateral spread and the density-distribution of electrons in a shower were calculated by L. Wolfenstein. The theoretical density-distribution computed for showers initiated by primary electrons was compared with the experimental data obtained by Lewis and Kingshill at Echo Lake and in Chicago. A large discrepancy exists between theory and experiment for both altitudes. The experiments show that most

air-showers have high-density cores of only a few meters extension, whereas the theory requires an extension of 60 meters from the center of the shower. This, however, does not mean that the cascade-theory cannot be applied to showers of very high energy. It is far more probable that the discrepancy is caused by the unjustified assumption that the extensive atmospheric showers originate from primary electrons of very high energy.

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## DIVISION OF PLANT BIOLOGY

*Central Laboratory located at Stanford University, California*

H. A. SPOEHR, *Chairman*

During the year under review the regular research programs which have been under way for some years have for the most part been put aside and the efforts of the staff directed to problems arising out of the war. As the war has progressed it has become evident that not only are there many problems directly connected with the aspects of combat and defense which must be solved by scientific methods, but a host of problems arising directly or indirectly out of the huge complexities of the conflict are in need of scientific investigation. The projects of the latter type were not nearly as urgent or obvious as were those dealing with combat and defense, but in the long run may be of equal importance. After a considerable preliminary study of a number of subjects of potential importance, the war effort and the post-war period, in which the facilities of the laboratory and the training of the staff could be turned to advantage, two projects were undertaken. To these the complete attention of the staff has been turned during the past year.

The first of these projects is concerned with the isolation of a new antibiotic, chlorellin, which is obtained from the green, unicellular alga *Chlorella*. The very noteworthy success of penicillin has encouraged the search for other substances produced by plants, which may be efficacious in cases not reached by penicillin or which may be produced more easily. Facilities for the culture of larger quantities of the organisms and methods for the extraction of chlorellin have been worked out, and some preliminary tests with animals have been made. These studies ap-

pear to offer sufficient encouragement to warrant further investigation.

It is difficult to realize that within so short a period as the past half-century one of our greatest natural food resources has been so completely exploited through mismanagement that it presents a serious national problem. This is the depleted livestock range of the West. The situation has apparently become aggravated by the increased demand for meat occasioned by the war. As a contribution to this problem, members of the staff, cooperating with the U. S. Soil Conservation Service, have undertaken a program directed to the production of new range grasses, utilizing principles recently worked out in the Division. For this program grass stocks from many different parts of the world are being employed. In 1943 seven different cross-pollinations between members of two sections of the genus *Poa* were made, and these have been augmented by twenty-four additional combinations tried under superior conditions during the present year. The hybrids which have been obtained demonstrate that species of *Poa* so remotely related as those employed can be crossed successfully. It is a cardinal aim of this program to obtain hybrids of remotely related parents, which not only will possess superior qualities, but will reproduce largely by asexual means and thereby continue indefinitely as "new species."

In planning the crossings, consideration is given to the morphology, native habitat, ecological preferences, seasonal behavior, and disease resistance of the selected parental strains. Hybrids are sought that will combine hybrid vigor and greater climatic

tolerance than their parents, drought and disease resistance, and greater soil-holding capacity, with a longer period of use for livestock. Some of the hybrids already obtained appear to combine favorably the characters of their parents, but their chances of success in nature will depend

upon the characteristics of their offspring, which must be determined by practical tests.

Owing to difficulties of travel and the fact that the staff has been otherwise engaged, very little field work has been done in any of the projects of the Division.

## BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, H. W. MILNER, AND G. J. HARDIN

### CHLORELLIN

The discovery that a mold, *Penicillium notatum*, produces a product of such remarkable properties as penicillin has instigated the examination of many other microorganisms in the hope of discovering similar, or even more useful, products. This search, carried on in many laboratories, has the objective of discovering antibacterial substances which are active against bacteria not inhibited by penicillin, or of finding substances which are efficacious under conditions in which penicillin is not. Most of the microorganisms which have been investigated in this search have been heterotrophic plants.

Prompted largely by the desire to make a contribution to the war effort, an investigation was initiated, cooperatively with members of the staff of the College of Pharmacy of the University of California, of the possibility of obtaining an antibacterial substance from cultures of the unicellular green alga *Chlorella*. This organism is autotrophic and, therefore, does not require organic material for its growth, only inorganic salts, carbon dioxide, and light being needed. For many years this plant has found extensive use as experimental material in the study of photosynthesis, so that considerable information regarding its culture had already been gained, although it had been grown only on a very small scale.

Recently it has been found that an antibacterial substance accumulates in uncontaminated cultures of *Chlorella* and that the activity of this substance can be tested by standard bacteriological methods. This substance has been designated by the name *chlorellin*, although it must be recognized that the products thus far obtained probably do not represent a pure chemical substance.

*Culture.* The organisms were grown in purely inorganic nutrient solution. Various proportions and concentrations of the essential inorganic salts have been tested. As a standard procedure, the following solution has been adopted as yielding most satisfactory results: 74 grams magnesium sulfate heptahydrate, 37 grams potassium dihydrogen phosphate, 38 grams potassium nitrate, and 0.02 gram ferrous sulfate heptahydrate in 15 liters of water. Water from various sources was tried; the most satisfactory results were obtained from a local well water which was boiled and cooled, allowing the precipitation of calcium and magnesium carbonates, and then filtered. These solutions, contained in 5-gallon "Pyrex" bottles, fitted with the necessary tubes for aeration, were sterilized in an autoclave. After cooling, 15 l. of nutrient solution were inoculated with 800 ml. of stock *Chlorella pyrenoidosa* cultures containing about 20,000 cells per cubic millimeter, thus making an initial

population of about 1000 *Chlorella* cells per cu. mm. The stock cultures of *Chlorella* were free of all other microorganisms.

After inoculation, the 5-gallon bottles were placed in a greenhouse in subdued daylight. A stream of 5 per cent carbon dioxide in air was continuously passed through the cultures. The gas stream was filtered through sterile cotton to avoid contamination by foreign organisms. The cultures were shaken several times a day. In the course of about 30 days the cell population grew to a density of about 40,000 per cu. mm. The temperature rarely rose above 30° C., and it was found that this temperature was not detrimental to the development of the organisms.

After having grown in the greenhouse for about 30 days under natural illumination, the cultures were subjected to continuous illumination from fluorescent lamps for 2 to 3 days. Although the matter has not been exhaustively examined, there is indication that the yield of antibacterial substance is increased during this period of continuous illumination. Needless to say, there remain many problems in connection with the culture of *Chlorella* for the production of chlorellin which require more careful investigation, and it is not improbable that many steps in the process can be greatly improved. The investigation of these problems is, of course, limited by the size of the staff, and it was felt that primary consideration should be given to the production of sufficient chlorellin, by the means now available, to provide the material necessary for chemical examination and for experimentation with animals as the critical test of its antibacterial properties. The *Chlorella* culture capacity consisted of forty 5-gallon bottles, from each of which 15 liters of culture solution could be obtained.

*Harvesting.* At the end of the period of illumination the cultures were examined

microscopically for contamination. Occasionally it was found that a culture was contaminated by bacteria, molds, or yeast. Such cultures were discarded. The *Chlorella* cells were separated from the culture solution by means of a Sharples supercentrifuge. The clear, slightly yellow, cell-free solution was used for the extraction of the chlorellin. This culture solution, at the time of inoculation, had a pH of 5.8; after growth of the cells and centrifugation, the solution showed a pH of 6.25-6.5. The *Chlorella* cells which were separated by centrifugation weighed 35-50 grams on a fresh-weight basis, or 10-15 grams dry weight, per 15-liter culture. It was found advisable to extract the centrifugates immediately, as they readily became infected with molds or yeasts.

*Extraction of chlorellin.* Various methods have been used to extract the active principle from the cell-free culture solutions, and the working out of this step of the process has, in fact, consumed a great deal of time. The most satisfactory results have been obtained by extraction of the solution with organic solvents or by means of columnar adsorption. For extraction with organic solvents, benzene, 1,2-dichloroethane, and chloroform have proved better than any other solvents tried, and of these three chloroform is the best. It has been found, however, that certain precautions must be taken in the use of chloroform as an extractant. When successive extractions are made with this solvent, especially in a continuous extractor, the chloroform undergoes decomposition, resulting in the formation of a small amount of material which itself possesses antibacterial properties and which accumulates with the extracted chlorellin. The formation of this material from the chloroform is variable in amount, and its exact chemical nature and the conditions which favor its formation have not been completely

determined. It is possible, however, to avoid the formation of this contaminant by adding 1 per cent of petroleum ether to the chloroform used in the extraction process.

The adsorption method consists essentially in percolating the cell-free culture solution through a column of "Florisil." For this purpose 30 cc. of acetic acid were added to each 15-liter lot of culture solution, which was then passed through a column 37 mm. wide and about 400 mm. long containing 200 grams of the adsorbent. Thereby the major portion of the inhibitory substance was adsorbed. It was then eluted from the adsorbent by permitting ethanol to percolate through the column.

The chloroform extraction method has the advantage of readily extracting the inhibiting material from the aqueous solutions, but requires considerable time (18 hours for a lot of 15 liters) and entails the use of relatively large amounts of chloroform. The adsorption method, on the other hand, is more rapid, 15 liters passing through a single column in about 4 hours, but it does not always effect complete removal of the inhibitory material. The adsorbent can be recovered and used again.

From the solutions, obtained either by means of chloroform extraction or by means of columnar adsorption, the solvents were evaporated at 55-60° C. with reduced pressure. The nonvolatile residues, consisting of yellow gums, amounted to about 0.1 g. in the case of the chloroform extraction method. The residues obtained from the alcoholic eluates on the "Florisil" columns were extracted with ethanol, the solutions filtered, and the solvent evaporated. The residual gums weighed 0.2 to 0.3 g. per 15 liters of culture solution. Older cultures yield larger quantities of nonvolatile residues, but these also appar-

ently contain larger quantities of material having no antibacterial activity. In all probability these residues are composed of mixtures of organic compounds. The antibacterial substance, or substances, contained therein are, however, fairly stable. Solutions thereof in chloroform may be heated for 18 hours to 60° C. without loss of activity, nor does the antibacterial material seem to be affected by mineral acids. No evidence has been obtained of the deterioration of the product by storage *in vacuo* for a month and more. Precise tests, however, over longer periods of time, and under the influence of other factors, have still to be made.

It is possible that the *Chlorella* cells themselves may prove to be a valuable source of the antibacterial substance. Active material has in fact been obtained from this source, but this extraction entails the separation of relatively large quantities of nonactive organic material, and as yet no simple means of accomplishing this has been found. In view of the fact that the use of this source would avoid the handling of large volumes of water, involved in the extraction of the culture solutions, the use of the cells probably warrants further study.

*Antibacterial tests.* It is difficult to compare quantitatively the antibacterial activity of chlorellin with that of other similar agents which have been more highly purified and the potency of which has been more rigorously defined. Besides the fact that chlorellin as thus far obtained constitutes a mixture of organic compounds, more satisfactory determination of potency depends upon more exact knowledge of its solubility, diffusibility, and other physical properties. An idea of the activity of a typical preparation may be gained from the following: From 15 liters of culture solution there were obtained by the adsorption method 0.25 g. of crude chlorellin.

This quantity was dissolved in 3 ml. of 67 per cent ethanol; 0.1 ml. of this solution by cup test (10 mm. diameter, 16 hours at 30° C.) against *Staph. aureus*, strain 209, produced a ring 18 mm. in diameter. Material prepared by the method of continuous extraction of the culture solution with chloroform (stabilized with petroleum ether) had antibacterial activity of the same order of magnitude.

Certain strains of *Staph. aureus* are known to be resistant to the action of penicillin. Cultures of such strains were kindly supplied us through Dr. Windsor Cutting, of the Stanford University Medical School, and the action of chlorellin was tested against these organisms. With cups 10 mm. in diameter, 16 hours at 30° C., chlorellin (prepared by adsorption) in 67 per cent ethanol produced rings of inhibition 18-19 mm. in diameter with the penicillin-resistant strains of *Staph. aureus*; a standard penicillin solution effected no inhibition, and the same chlorellin solution produced rings of 20 mm. with *Staph. aureus*, strain 209.

Through the cooperation of Dr. Cutting,

some animal tests have been made with chlorellin. In the tests which have been made thus far with mice, no evidences of toxicity have been observed from the injection of aqueous or ethanol solutions of chlorellin.

Up to the present time sufficient chlorellin has not been available, and this has been of too low potency, to carry out critical tests with infected animals. In order to meet the requirements for animal experimentation, it is clear that considerably more work will be required to effect the purification of the crude chlorellin preparations which have been obtained thus far. This must be done with a view to determining something of the chemical nature of the active substance.

The fact cannot be disregarded that many bactericidal and bacteriostatic substances can be obtained from a wide variety of plants. Which among these will prove to be useful chemotherapeutic agents can only be determined upon the basis of careful study, in which chemical, biological, and clinical research must move hand in hand.

## EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, AND WILLIAM M. HIESEY

The main efforts of the group investigating basic laws of plant relationship are currently being given to the synthesis of new grasses suitable for western ranges. The western range has been rapidly depleted in modern times, and the present national emergency has emphasized again the importance of this primary source of food. Past studies by our staff on natural species have yielded background information that would be useful in such a breeding program, and it was desirable to subject these principles to practical testing (Year Book No. 42, pp. 97-99). At the same time it was realized that if sound

scientific methods were followed in the breeding, such experiments should clarify certain principles in ecological genetics, a relatively new field of importance for investigations on plant relationships.

This program was undertaken in cooperation with the Pacific Coast Division of the Soil Conservation Service of the U. S. Department of Agriculture, which has furnished most of the original breeding stock from its nurseries at Pullman, Washington, and Pleasanton, California. These stocks were supplemented by strains on hand and those collected along our station transect. The many courtesies received from the

Soil Conservation Service have proved invaluable.

Supplementary strains of grasses have been received from Dr. G. L. Stebbins, Jr., of the University of California Agricultural Experiment Station at Berkeley.

Owing to a late start in 1943, it was possible to perform only seven different cross-pollinations between members of two sections of the genus *Poa* in that year. The resulting seeds were sown in 1944, and among the 3300 offspring some 32 hybrids were found, or nearly 1 per cent of the total. This demonstrated that such intersectional hybrids could be made in *Poa*, a point which had been debatable when the work was begun with this genus.

#### THE DEPLETION OF THE WESTERN RANGE

The range area of the West, as outlined by the U. S. Department of Agriculture, comprises nearly 40 per cent of the total land area of the United States. This vast region of low rainfall and often rough topography supports mainly native forage plants and is very largely unsuitable for any other form of agriculture. It has undergone serious deterioration through misuse and abuse. The Forest Service estimates that, as compared with its virgin condition, forage depletion of the entire range area averages more than 50 per cent. As of 1936, some 17.3 million animal units were being grazed on ranges which it was estimated could carry only 10.8 million, and this compares with an original carrying capacity of 22.5 million units. In this way we have seriously depleted one of our most important natural resources, and the demands of the war are certain to deteriorate it further.

Some natural resources, such as petroleum, cannot be replenished. The western range is one resource that can be both utilized and by proper action replenished,

but if no action were taken to save it, it would become largely unreclaimable desert.

The western range must be built up again, but the process is necessarily a very slow one even under careful management. One of the ways in which to improve the range is to preserve and propagate the best strains of grasses now occupying it. The Soil Conservation Service is working in this direction. Another way is to combine some of the best native species, through hybridization, to form fertile constant hybrid derivatives that are superior to their ancestors.

#### BREEDING OF RANGE GRASSES

It is strange that only scattered attempts have been made at breeding forage grasses, when so much progress has been made in improving cereals and sugar-producing grasses. Although the keeping of livestock is one of the earliest forms of agriculture, the forage grasses have remained much as they were when man found them. There is no reason to doubt that there are extensive opportunities for improvement in these forms.

Plants to be grown on the range must be able to take care of themselves with a minimum of management. This requires that they possess the characteristics of wild species of the region. Consequently, the breeding of range grasses is a very different undertaking from that of breeding cereals, which are intensively cultivated crops.

New species arise from old ones which furnish the building materials. But natural species are characterized by intricately balanced systems of genes that determine their characteristics and development. This balance is difficult to obtain, and it is usually disturbed when two species interchange their genes after crossing. Weak offspring indicate disturbed development in the later generations of such crossings.

It is therefore a difficult task to build new species.

Gene interchange is avoided in those cases in which distinct species form constant, nonsegregating hybrids. Such crossings make it possible to combine the desirable characteristics of two species and to preserve the hybrid vigor that is so characteristic of many first-generation hybrids.

Nonsegregating hybrids can be obtained in two ways. One of these is through doubling of the chromosomes of an interspecific hybrid (amphiploidy). This requires that the parents be related so remotely that their chromosomes cannot pair, yet closely enough so that their genes work harmoniously together—requirements that have been generally overlooked.

Practically nonsegregating hybrids can also be obtained in those relatively uncommon groups of plants that usually produce seed without fertilization, through facultative apomixis. The hope for production of hybrids in these lies in the fact that a small percentage of their offspring is produced sexually, through pollination followed by normal fertilization. These sexually produced individuals are believed to propagate for the most part asexually again.

The nonsegregating hybrid is important also in another connection. Hybrids between species or forms that are fitted to very different climates often are able to tolerate greater differences in environment than their parents, or than hybrids between species from one environment. A nonsegregating hybrid is needed for the proper utilization of this greater adaptability, for in any one environment the survival would be poor if the hybrid segregated in respect to its ecologic fitness.

Range grasses are needed that are both vigorous and adaptable to a series of environments. Nonsegregating hybrids that combine the inheritances of remotely re-

lated species from very different climates might be expected to have these characteristics.

At its Pullman nursery the Soil Conservation Service gives particular attention to two groups of grasses that are considered among the most useful for the western range, both as feed and for their soil-holding power. These are (1) the bluegrasses of the genus *Poa*, and (2) the wheat grasses and wild rye of the genera *Agropyron* and *Elymus*. Both of these groups would lend themselves to this type of breeding. The agriculturally most important species of *Poa* are partially apomictic, producing seed without fertilization. The *Agropyron-Elymus* group has sexual species, but some of them should be mature for evolution through amphiploidy, that is, chromosome doubling following interspecific hybridization. Extensive series of species and races of these three genera were grown in the Carnegie Institution garden at Stanford University during 1944 for study and comparison.

The successful production of intersextional hybrids in *Poa* has led to the concentration of effort on that genus at present. This is because it is in such partially apomictic groups of species that one may most reasonably expect to obtain definite improvements within the period of a few years.

#### TAXONOMY AND DISTRIBUTION OF POA

The genus *Poa* contains about 100 species, natives of warm-temperate to arctic regions. The very complex relationships in the genus as a whole have not as yet received a satisfactory taxonomic treatment. It appears that the genus is divisible into several natural sections. For western needs, the species of most promise for breeding are contained within two sections. One of these, not yet formally

recognized, contains the various bunch-grass species of western North and South America. The other contains the rhizome grasses related to *Poa pratensis* L., and is the *Pratenses*.

Among the forms of the bunch-grass section that are being used is *Poa scabrella* (Thurb.) Benth., a medium-tall, rather early grass of the California Coast Ranges and the foothills up to medium altitudes in the Sierra Nevada. Related ecotypes ascend nearly to 12,000 feet altitude. In the drier habitats to the east and north, to Washington and Montana, is *Poa secunda* Presl, the Sandberg bluegrass, a native of both North and South America. It is one of the first species to flower in the spring and the first to go dormant. *Poa ampla* Merr., the big bluegrass, centers in the Palouse Prairie of eastern Washington and Oregon and contains some races nearly 2 meters high. It avoids the moist meadows and flowers late. A close relative is *Poa nevadensis* Vasey, occurring southward in the Great Basin, but in somewhat the same region, although usually at higher elevations and in moister sites. It is also a late-flowering grass.

The most important species of the rhizomatous section *Pratenses* is *Poa pratensis* L., a world-wide species known in America as Kentucky bluegrass. Including *Poa alpigena* (Fr.) Lindm. as merely a northern subspecies of it, this grass is circumboreal and circumpolar in distribution, with ecotypes adapted to temperate and high arctic latitudes, lowland and alpine altitudes, and moist meadow to dry hillside habitats. Although it is commonly believed to have been introduced into America from Europe, it behaves like a native in the Sierra Nevada of California, where it occurs between 3000 and 6000 feet on the west side and below 7500 feet on the east side of the range. The intervening higher elevations in the Sierra Nevada, between

7000 and 12,000 feet, are occupied by the closely related *Poa nervosa* (Hook.) Vasey, of relatively drier habitats. Another promising species of the section *Pratenses* is *Poa arida* Vasey of the Great Plains. The Canada bluegrass, *Poa compressa* L., is a European introduction that is commonly cultivated in America and is of drier habitats.

#### BIOLOGICAL CHARACTERISTICS OF POA AND BREEDING TECHNIQUE

Most of the economically important species of *Poa* have high chromosome numbers and many unpaired chromosomes, as in certain interspecific hybrids. In spite of the cytological irregularity, little segregation is usually observed in their offspring, for they appear to reproduce largely by seed obtained without fertilization, although the stimulus of pollination is necessary. Most of the offspring is therefore the exact counterpart of the parent.

When seed is occasionally produced by cross-fertilization, it yields highly variable offspring, as would be expected if hybrids were crossed; but later generations are again essentially constant, because they arise largely asexually. Each interspecific hybrid potentially represents a new form, or even a new species, and sister plants of the first generation will often differ considerably in their chromosome number. For practical breeding purposes the small percentage of sexually produced offspring that will appear in later generations can be disregarded as of almost no consequence in affecting the characteristics of the whole population. Moreover, natural selection operates to preserve only the superior forms. Consequently, in *Poa*, successful new forms can be selected among the first-generation hybrids. This advantage very materially shortens the period ordinarily required for developing new forms.

In species like those of *Poa* that normally produce their seed without fertilization, emasculation is of little use in the crossing technique. Also, many of the interspecific hybrids obtained will doubtless be genetically and physiologically unbalanced, and only the best will be of importance in the range-grass program. Consequently, in order to produce a sufficient number of hybrids, a mass pollination technique is employed without emasculation. By crossing members of distinct sections of *Poa* that differ in many characters, it is possible to recognize most of the hybrids in the seedling stage in the greenhouse, thereby avoiding the task of transferring the high percentage of maternal-type plants to the garden. Also, the remotely related inter-sectional hybrids are the most promising for producing nonsegregating, asexually propagated new species.

A set of 16 large pollen-tight tent cages was built for outdoor pollination. Vigorous plants intended for crossing are grown in 8-inch pots, where as many as 100 inflorescences may develop. Two plants that are to be mutually pollinated are placed in a cage and the pots are sunk in the ground. Pollen of each plant is collected daily in parchment bags placed over the inflorescences in the late afternoon. In the morning the pollen is shaken into the bags, which are then exchanged between plants and shaken vigorously to insure concentrated cross-pollination of the florets within.

The species and races differ markedly as to the time when they start flowering under uniform garden conditions. At Stanford the earliest begin in late February and the latest in early June. Any one form flowers over a period of approximately three weeks. It will therefore require special treatment to bring certain forms into flowering at the same time.

#### PERIODICITY AND DISEASE RESISTANCE

Information is being systematically gathered on the periodicity of growth and the resistance to disease of the races and species as grown at Stanford. This will aid in planning additional crossings.

Great differences in periodicity are apparent. In the gardens at Stanford the western bunch grasses tend to be very active through the winter and spring months, but they go dormant during the summer. The winter activity is striking in the big bluegrass, *Poa ampla*, from eastern Oregon and Washington, and in *Poa scabrella* from the California Coast Ranges. Although *ampla* comes from the north, some of its races develop in the garden during February extremely vigorous dense rosettes of leaves up to 45 cm. high. The leaves dry up when flowering starts, and both *ampla* and *scabrella* go dormant at the approach of the dry season, *ampla* remaining green the longer. Their forms from higher elevations, however, tend to go dormant during the winter. *Poa secunda* from the dry ranges east of the Cascades and the Sierra Nevada has the most rigid periodicity. Even the young seedlings go completely dormant in May without having flowered, irrespective of the amount of soil moisture.

Among the species of *Poa* with rhizomes, *pratensis* and *arida* tend to go dormant during the winter at Stanford, but they renew their activity in late February, developing a spring crop of short leaves, and flowering follows some time later. Unlike the bunch grasses, however, they do not go dormant after flowering, but develop a summer crop of very long leaves, a characteristic that it would be desirable to combine with the winter growth habit of the bunch grasses. *Poa nervosa*, from the high Sierra Nevada, has a very unusual behavior for an alpine species, since it flourishes

under the lowland conditions, remaining green all winter and developing many tall culms in the spring, but, unlike *pratensis*, going dormant during the summer. Only one other alpine species has thus far shown this kind of reaction pattern with us, namely, *Potentilla Drummondii* Lehm.

The development of many diseases is favored by the long growth period and mild climate at Stanford, hence the gardens here are a favorable place for testing disease resistance. Races native to higher altitudes and latitudes usually become badly attacked by rusts and mildew here, whereas forms native to the California Coast Ranges are relatively resistant. Outstandingly resistant forms, however, have been found among races native to high altitudes, and two completely resistant forms of *pratensis* originated in high latitudes. Although it is realized that many forms which are weak and susceptible to disease in the gardens at Stanford may be healthy in another environment, the most disease-resistant forms have been almost exclusively used for the crossings.

#### CYTOTOLOGY OF *POA*

Miss Marguerite Hartung has been investigating the chromosomal situation in the species and hybrids of *Poa*. This genus presents technical difficulties for chromosomal investigations. On account of the many unpaired chromosomes and their irregular behavior, it is impossible to count the chromosomes when the sex cells are formed in the flower buds. Furthermore, in the economically important species the chromosome numbers are very high, a fact which increases the difficulty of obtaining quick, accurate counts. A satisfactory technique has now been found for the preparation of root tips so that the chromosomes can be counted with fair

certainty. The following chromosome numbers have been determined:

#### Bunch-grass species:

<i>Poa ampla</i> Merr., 12 races	$2n = ca. 63$
<i>Poa nevadensis</i> Vasey, 7 races	$ca. 63$
Same, 1 race	$ca. 70$
<i>Poa scabrella</i> (Thurb.) Benth., 5 races	$ca. 84$
<i>Poa Canbyi</i> (Scribn.) Piper, 6 races	$ca. 84$
<i>Poa secunda</i> Presl, 3 races	$ca. 84$
<i>Poa Canbyi</i> $\times$ <i>ampla</i> , natural hybrid (?)	$ca. 88$
<i>Poa longifolia</i> Rich., Armenia	43

#### Rhizome species:

<i>Poa pratensis</i> L., Sierra Nevada, 4 races	$2n = ca. 68-70$
Same, N. Saskatchewan or Alberta	70
Same, Lapland	$ca. 74$
<i>Poa nervosa</i> (Hook.) Vasey, 3 races	$ca. 63$
<i>Poa arida</i> Vasey, Nebraska	63
<i>Poa compressa</i> L., Chorsum, Asia Minor	50

The chromosome numbers follow an arithmetical series with 7 as the basic number. Several European species of *Poa* have just 7 pairs of chromosomes. It appears, however, that slight deviations from the regular multiples occur. In *Poa ampla*, for example, forms with 62 and 64 chromosomes have been determined with reasonable certainty in addition to those with 63. The deviations from the straight multiples of 7, however, are slight.

Plants belonging to one systematic unit appear to have approximately the same number of chromosomes. In this respect the situation differs from that found in *Potentilla gracilis* Dougl. ex Hook., another species complex with asexual propagation, which was investigated during the transplant experiments (Year Book No. 38, p. 124). In this species the chromosome

number was found to vary even within the local population.

Unbalanced, or uneven, sets of chromosomes occur in these bluegrasses, for *Poa ampla*, *nevadensis*, *nervosa*, and *arida* have approximately 9 sets of 7 chromosomes each ( $2n = 63$ ), and the *compressa* form investigated had approximately 7 sets ( $2n = 49 + 1$ ). Obviously, the chromosomes in such forms will be unable to pair regularly. The relative chromosomal uniformity within systematic units so constituted cytologically is good evidence that these species propagate primarily by asexual means.

Groups of plants that are propagated only partially by asexual means are so mixed up through hybridization that species in them comparable to those found in sexual plants do not exist. Consequently, classification in such groups must be rather arbitrary and follow practical considerations. The systematic units of the western American bunch-grass Poas listed above are based mainly on their ecology and their reactions under cultivation, but as to chromosome number they fall into two major groups, namely, those with 63 and those with 84 chromosomes, which correspond to the "sections" *Nevadenses* and *Scabrellae* of Hitchcock's treatment. By no one set of morphological characters can the systematic units unfailingly be recognized, although the extreme forms of neighboring units stand out distinctly. In spite of this difficulty, there is no doubt but that the forms referred to in the chromosome list are all very good biological units.

*Poa longifolia* probably propagates sexually, for the plant investigated had 21 pairs and 1 single chromosome, easily counted in meiosis. This very vigorous species is morphologically closely related to the European *P. Chaixii* Vill., which is reported to have only 7 pairs of chromosomes.

#### HYBRIDIZATION OF *POA*

The following objectives guided the selection of plants for crossing: (1) to combine members of distinct sections in order to insure hybrid vigor and easy recognition of the hybrids; (2) to combine plants native to different climates in order to obtain a greater climatic tolerance; (3) to combine the drought resistance of the bunch grass with the greater soil-holding capacity of the rhizome grass, and to utilize the better storage facilities of the rhizome grass as an additional protection against overgrazing and fire; (4) to lengthen the season of use by combining winter- and spring-active bunch grasses with summer-active rhizome grasses; and (5) to breed for disease-resistant forms. It is most fortunate that the desirable characteristics of *Poa* are so distributed among its species that in most crossings it is possible to aim for all these objectives at once.

The scope of the crossings can best be illustrated through examples. At least four hybrid combinations were successful, as follows:

- Poa ampla*, SE. Washington,  $2n = 64$ ,  $\times$  *pratensis alpigena*, Lapland,  $2n = 74$ , 9 hybrids.
- P. ampla*, SE. Washington,  $2n = 63$ ,  $\times$  *compressa*, Asia Minor,  $2n = 50$ , 12 hybrids.
- P. pratensis alpigena*, Lapland,  $2n = ca. 74$ ,  $\times$  *Canbyi*, Blue Mts., Washington,  $2n = 84$ , 8 hybrids.
- P. Canbyi*, Blue Mts.,  $2n = 84$ ,  $\times$  *pratensis*, W. Canada,  $2n = ca. 74$ , 2 hybrids.

The *alpigena* form of *Poa pratensis* from Lapland was used frequently in the 1943 crossings, because it was the only form of the species in bloom with most of the bunch-grass Poas. It flowers continuously for about three months under California conditions, but does not grow so tall as in its native home about 2° north of the Arctic Circle. Unlike most subarctic plants,

however, it thrives and flowers without special attention 30° farther south at Stanford, under conditions extremely unlike those of its native wet meadows. It proves to be both drought-resistant and disease-free at Stanford. The hybrids between it and the giant form of *Poa ampla* combine several desirable characteristics from outstanding parents native to very different climates.

Another promising combination unites the same 6-foot strain of *Poa ampla* and a much smaller but drought- and disease-resistant rhizome grass, *Poa compressa*, from the Mediterranean slopes of Asia Minor.

The best *pratensis* form on hand is the "Delta" strain, a selection made by Dr. L. E. Kirk of a plant from western Canada, probably the Athabasca region. This strain is very vigorous and productive at Stanford, where it is free from disease, but it flowers so early that it is difficult to cross with the bunch grasses. Only two hybrids have been obtained between it and a form of *Poa Canbyi* from the Blue Mountains of southeastern Washington.

During 1943 the choice of plants for crossing was very limited, and true mass pollination was approached in only one cross. In the spring of 1944, however, the desired parents were in excellent condition, so that mass pollinations were made in twenty-four additional combinations during the period from March through June. This seed will be sown in 1945.

When the rare functional sex cells are formed in these species, the unpaired chromosomes are distributed irregularly to them. Consequently, the hybrids of any one combination will usually differ both in chromosome number and in appearance. Giant pollen, presumably containing the unreduced number of chromosomes, has also been observed.

Because of this situation, not only sister

hybrids, but also the corresponding non-hybrids produced sexually will show distinct variations in their chromosome numbers. The following two series illustrate this:

*Poa ampla*  $\times$  *pratensis alpigena*  $F_1$ :  $2n = 63$ , 68, 68, 70, 72, and 92.

Same, but nonhybrid sexuals:  $2n = 60$ , 61, 62, 66, 70, 88, 92, and 93.

*Poa ampla*  $\times$  *compressa*  $F_1$ :  $2n = 50$ , 57, 60, 70, 82, 86, 91, 99, and 100.

Same, but nonhybrid sexuals:  $2n = 54$ , 60, 68, 83, 92, and 139.

The above chromosomal situation explains the very noticeable morphological variation found in these hybrids. Those with about 90-100 chromosomes are approximately triploid, and are evidently produced by the combination of two genomes of *ampla* (a diploid gamete) and one genome of the pollen parents. In this manner, hybrids that have various proportions of chromosome sets of the parental species can be obtained.

The rather small percentage of non-hybrid sexually produced individuals arose from self-pollination. They differ not only in chromosome number but in appearance from each other and from their parent, and they are usually weaker than the numerous sister plants that arise asexually.

When one attempts to produce new hybrids that propagate in part asexually, it is important to know how constant such forms must be in order to become established as a natural unit. A fair standard should be provided by the existing wild forms of the group. It is shown above that they produce some aberrant offspring with highly deviating chromosome numbers. For this reason it is desirable to know what proportion of their seed develop, germinate, and produce maternal-type plants. Two examples will illustrate the trend.

The giant *Poa ampla* referred to above is a rather highly constant type, in which approximately 91 per cent of the seedlings were of the vigorous maternal type, but so many seed failed to develop or germinate that these maternals represented only some 24 per cent of the original possibilities. About 5400 seeds were harvested from 13 inflorescences of *ampla* pollinated by *compressa*, but 2500 of these were aborted, and of the remaining 2900 only 1473 germinated. These produced 1311 very vigorous maternals, 9 hybrids, and 146 more or less weak aberrants, and only 7 of them died after germination. Despite the losses, this plant produced some 100 plants of maternal type per inflorescence.

The other extreme is represented by *Poa pratensis alpigena*, in which the offspring is highly variable, and only some 30 per cent of the seedlings are of the vigorous maternal type. In this case, however, there is much less loss through poor seed and poor germination, so the net result is about the same as in *ampla*, with about 20 per cent of the original possibilities resulting in maternals. The others are weak individuals that are promptly crowded out by the competition. With much smaller panicles than *ampla*, the *alpigena* form was able to produce about 30 strong maternals per inflorescence.

A principal difference between *ampla* and *alpigena* is therefore that in *ampla* the elimination of unfit combinations produced sexually takes place even before germination, whereas in *alpigena* many of these germinate but are unsuccessful in competition. In both cases it is the maternal-type plants, produced asexually, that do succeed. One task in the breeding program is therefore to select vigorous hybrids whose asexually produced offspring are sufficiently abundant and vigorous to outgrow those offspring produced by sexual means.

#### TESTING OF *POA* HYBRIDS

The three altitudinally distinct transplant stations of the Division are important assets in the grass program. They represent differences in climate ranging from warm temperate to arctic-alpine. Moreover, large numbers of species from many environments have already been grown there to calibrate the station climates, for plants native to various climatic zones have shown distinct reaction patterns there. It should therefore be possible to gauge roughly the potentialities of a new constant hybrid by growing parts of it simultaneously at the three stations and noting the reactions. Some of the most important parental strains have already been planted there this year, and, transportation permitting, some of the hybrids will follow in 1945. These preliminary tests should determine the approximate climatic region for which the form is fitted, but the final field tests are to be made by the Soil Conservation Service. A comparison of the reactions and tolerances of the hybrids and their parents is expected to yield basic information needed for the formulation of certain fundamentals in ecological genetics. *Poa* offers exceptional advantages for a broad-scale testing of these principles, where scientific exploration and practical application may go hand in hand.

#### PHYSIOLOGY OF CLIMATIC RACES OF *ACHILLEA*

It may now be considered well established that climatic races, or ecotypes, are basic in the pattern of plant life. Numerous experiments with ecotypes of *Potentilla*, *Zauschneria*, and species of the *Mat-dinae* reported in previous Year Books have shown that both their morphological and their physiological characteristics are determined by genes, and that the gene balances are rather intricate. Little is

known, however, as to how such physiologic differences operate. The war forced the suspension of investigations that had been designed to explore the functional differences between related climatic races (Year Book No. 41, pp. 132-134).

An opportunity to study the growth of climatic races under controlled conditions was afforded through the kind invitation of Dr. F. W. Went, of the California Institute of Technology, who offered the use of space in the laboratories and controlled greenhouses at Pasadena for this purpose. These greenhouses are well adapted for a study of the effect of differences in temperature and light. A description of them has been published by Dr. Went (Amer. Jour. Bot., vol. 30, pp. 157-163, 1943). Following this invitation, Dr. Hiesey spent January to May 1944 at Pasadena in an investigation designed to explore the physiological differences between climatic races by comparing their growth under various known sets of conditions.

Plants of the *Achillea millefolium* complex were used for this study. Possibly no other group of plants has developed so complete a series of ecotypes for altitudes between sea level and 12,000 feet, and for latitudes from warm temperate to arctic (Year Book No. 41, pp. 127-132). Also, these plants offer certain practical advantages in experimentation because of their ease of propagation, both vegetatively and by seed.

Individuals of thirteen distinct races were propagated from a uniform plot at Stanford and taken to Pasadena. These were typical representatives of each climatic race from the transplant station transect across California at 38° north latitude, at elevations from sea level to 10,000 feet, and of races from Alaska, Denmark, and Lapland. Each individual was divided into a number of ramets for simultaneous study in a number of controlled environments,

in order to insure the genetic identity of each race compared. The plants were potted in sand, watered daily with nutrient solution, and placed under various sets of day and night temperatures.

During the four-month period of the experiment marked differences in reaction of the ecotypes were observed. Two races from the cool fog belt of the California coast (from near Bodega, Sonoma County, and San Gregorio, San Mateo County) developed poorly when grown at a constant day and night temperature of 26° C., whereas a form from Selma, in the hot San Joaquin Valley, flourished and freely flowered. All three of these races grew vigorously and produced many flowering stems under a day temperature of 17° C. and a night temperature of 13°, but when the night temperature was cooled to 7°, the growth of the Selma race was greatly inhibited, although the coastal races grew almost as rapidly and flowered as freely as at 13°. From these and other experiments it is clear that at the higher temperatures growth of the Selma race is favored over that of the coastal races, whereas the coastal races exceed the one from Selma under the cooler conditions.

The pattern of reaction in a mid-Sierran race from Mather, at 4500 feet elevation, differed from that observed in either the coastal races or the Selma race, for in this ecotype excellent growth and flowering took place at a day temperature of 26° and with a cold night of 7°—conditions under which neither the coastal nor the Selma races grew nearly as rapidly. This result is consistent with the fact that the summer growing conditions at Mather are characterized by clear, hot days and cold nights.

Under the intermediate condition, represented by a 17° day and a 13° night, the coastal, Selma, and Mather races all thrive, apparently because in this environment all are within their ranges of physiological

tolerance. In the extreme environments, the greatest differences in reaction are seen. Thus the mode of operation of natural selection in the wild begins to become evident.

Races from high altitudes in the Sierra Nevada reacted very differently from those of lower elevations, indicating distinctive physiological characteristics. Alpine and subalpine races from 10,000 and 8200 feet elevation remained dormant throughout the four-month period at 17° day and 7° night temperatures, in marked contrast with the behavior of the coastal forms, which grew vigorously and flowered. They did become active, however, when the day temperature was 26° and the night 7°, indicating that the critical day temperature for the interruption of dormancy in these high-altitude races is somewhere between 17° and 26°. This would point to the existence in the alpines of a sensitive physiological mechanism governing dormancy, that is determined by temperature.

In order to flower, alpine and subalpine races appear to require more light than the races from lower altitudes, which would flower even with an 8-hour day. None of the plants from high altitudes flowered or even thrived under such short periods of illumination, but their growth was greatly accelerated and flowering stimulated in natural daylight for 8 hours at 26°, supplemented by fluorescent light of 450 candle-power intensity for the remaining 16 hours at 17°. Under these conditions the acceleration of growth was noted also in races from lower altitudes, but the increase of vigor, and especially the stimulus to flowering, was relatively much greater in the alpine and subalpine forms. In their native high-altitude environments of high light intensity, these races flower when the days are long, whereas the plants from lower altitudes flower

earlier, when the days are somewhat shorter.

Forms from northern latitudes, including a coastal race of *Achillea borealis* from Seward, Alaska, at 55° north latitude, and a continental race of *A. millefolium* from Lapland, north of the Arctic Circle at 68° north latitude, differed from the California forms in showing much less marked reactions to changes in temperature. The general health and vigor of these plants was excellent under all the temperatures, even at a constant day and night temperature of 26° C. Their general vigor and less marked reactions to different temperature treatments indicate a very wide range of physiological tolerance, which is in accord with the observation that they, unlike many other species from northern latitudes, thrive in the California transplant gardens far south of their native habitats.

These exploratory investigations, only partially outlined above, have thrown new light on the nature of ecotypes and the processes of natural selection. They have demonstrated the value of growing climatic races under controlled conditions as a step toward analyzing their physiological differences. This method, if applied to the grass-breeding program, could determine more exactly the physiological tolerance of the hybrids as compared with their parents, and suggest the kind of climates for which they might be fitted. An interpretive report on these controlled-environment studies, together with an analysis of the results from growing many populations of many ecotypes of *Achillea* at the three transplant stations, is now in the course of preparation.

#### OTHER INVESTIGATIONS

The monographic study on the evolutionary significance of amphiploidy and autoploidy discussed in the last Year Book

is now appearing as Publication 564 of the Institution.

The need for giving the grass-breeding program a sound start has temporarily withdrawn much of the attention that was being given the other programs in progress. The following advances, however, should be mentioned.

*The Madiinae.* The experimental work on this group of some 85 species is now essentially complete and awaiting the preparation of final reports. During the past year three  $F_2$  hybrid populations were grown, involving some 1600 plants. These cultures were within the species complex of *Hemizonia congesta* DC., of the section *Euhemizonia*. They complete the experimental work within that section by determining the status of *Hemizonia multicaulis* Hook. et Arn., a species unrecognized in the California flora since its publication in 1838. Examination of the type, borrowed from Kew, which was collected in California by Douglas in 1831 or 1832, showed that this was identical with the extreme coastal form with yellow flowers found north of San Francisco Bay. It had usually been referred to the somewhat more inland yellow-flowered form first described as *H. luzulaefolia* var. *lutescens* Greene, and in spite of many morphological and reactional differences between the two, the first inclination was to consider them as ecotypes of one species. But the genetic experiments disclosed that although the first-generation hybrid was vigorous and fairly fertile, the second generation was much inferior, with only a small percentage of the plants approaching the parental types in vigor. This indication of distinct genetic barriers between the two forms, preventing free interbreeding, means that *H. multicaulis* is a maritime, and *lutescens* an inland, ecospecies. Both belong to the cenospecies *H. congesta*, which contains now in all seven ecospecies,

each with 14 pairs of chromosomes (Year Book No. 36, pp. 210-211). Progress has also been made in preparing the chromosomal illustrations for the *Layia* publication.

*The genetic basis of ecotypes.* Large populations of *Potentilla glandulosa*, which take about three years to mature, have been genetically analyzed and tabulated in the gardens at Stanford. These included 24 populations from the wild, representing samplings of the climatic races from 1000-foot intervals from sea level to 11,000 feet along the central California transect, as well as many  $F_3$  populations from a cross between the foothill and alpine ecotypes. The  $F_2$  parents of these were among the plants studied in the selection experiment (Year Book No. 39, pp. 162-163), and their reactions are therefore known. Also, a large  $F_2$  population was analyzed of a cross between the coastal ecotype from near Santa Barbara and a high-alpine ecotype from 11,000 feet in the Sierra Nevada. These populations totaled about 6000 plants.

First-generation hybrids between alpine and lowland forms of this species are considerably more vigorous than either parent, and unlike the latter they survive well at all three transplant stations, a fact which indicates their greater ecological tolerance. The analyses of the  $F_2$  and  $F_3$  populations indicate that several genes are responsible for each of the many morphological and physiological characteristics that distinguish the ecotypes, that there is considerable linkage between the many genes of these ecotypes which have only 7 pairs of chromosomes, and that the very important reactional characteristics that adapt the ecotypes to their habitats segregate like the morphological ones, to which they are often linked, indicating a gene basis for both.

Although the genetic differences are

highly complex between these extreme climatic ecotypes, nevertheless their genes are completely interchangeable. All sorts of recombinations of the parental characters were observed in these populations, but still the vigor was generally better than in the parental forms. This hybrid vigor continued into the  $F_2$  generation, in striking contrast with the results observed in the crosses between ~~ss~~ distinct ecospecies of *Hemizonia* mentioned above, proving

that in *Potentilla* these morphologically distinct climatic races are but ecotypes of one species.

The experimental work on *Potentilla glandulosa* has now been concluded. The data mentioned above, together with those from the selection experiment and from hybrids between distinct ecotypes of the Madiinae, now await final analysis and publication as a study on the genetics of climatic races.

## DESERT INVESTIGATIONS

FORREST SHREVE

The desert projects have been advanced during the past year chiefly by the study of notes and materials gathered in the years of active field work and by the preparation of maps, drawings, and manuscript for publication. A limited amount of field work was carried on in the Chihuahuan Desert. The preparation of a manuscript covering the ecological aspects of the work done in the Sonoran Desert is approaching completion. The progress of the Flora of the Sonoran Desert has been interrupted by the departure of Dr. I. L. Wiggins for Ecuador, where he is engaged in field work on cinchona. Manuscript for this Flora has been completed by Dr. Wiggins as far as the Cruciferae and for a large part of the Leguminosae, as well as for several smaller families. It is hoped that this project can be resumed and ultimately pushed to completion as planned. Dr. I. M. Johnston has actively continued his work on the plants of the Chihuahuan Desert and has published two papers embodying his preliminary treatment of the plants of Coahuila and adjacent parts of other states. He has now covered the Monocotyledoneae and the Dicotyledoneae as far as the Allioniaceae.

In the spring of 1944 a short visit was made by Dr. Shreve to the southwestern

borders of the Chihuahuan Desert in Zacatecas and Jalisco. Difficulty in securing local transportation restricted the area that it was planned to cover. All the field work previously done in the Chihuahuan Desert had been in the late summer, when the vegetation is at its maximum development as a result of the summer rains. Little was known about the condition of the vegetation after the light rains of winter and during the period of low temperatures, the effect of which would normally be greatly influenced by altitude and slope exposure. Although the winter of 1943-1944 was below normal in precipitation, it was found that the late winter and early spring months are a period of marked inactivity. All deciduous trees, including the characteristically abundant Leguminosae, are leafless; the great majority of shrubs and small perennials are leafless or in a state of almost complete vegetative inactivity. The grasses are brown, and there are no active herbaceous annuals or bulbous perennials. In many situations there are evergreen trees or shrubs, but they rarely form extensive stands. A few species of trees and shrubs were in bloom during their leafless winter period. The winter growing conditions appear to be far poorer on the whole at elevations of 4000 to 7000

feet on the southern edge of the Chihuahuan Desert than they are in the region of biseasonal rain in the Sonoran Desert at elevations of 1000 to 3000 feet.

In the late summer of 1943 Mr. U. T. Waterfall continued his exploration and collecting in west Texas. Knowledge of the plants of this region has been largely based on the thorough collections made during the past 40 years in such promising localities as the Davis and Chisos Mountains. Mr. Waterfall has visited a number of the smaller ranges of mountains as well as some of the very arid valleys, and his collections contribute toward a better understanding of the floristic areas in this rather complex region. Many plants known from the southern tip of the Big Bend have not yet been detected elsewhere in Texas. The presence of certain Mexican plants in the Guadalupe Mountains, which extend into New Mexico, is now supported by their discovery in the Sierra Diablo. The results of the work in Texas indicate that there, as elsewhere in the desert, endemism is stronger in the arid valleys than it is under the more favorable conditions of the isolated mountain ranges, covered in part with mesic vegetation.

In connection with the study of climatic conditions in the desert, a paper has been published on the seasonal and distributional features of rainfall in the Sonoran and Chihuahuan deserts. Areas with less than 200 mm. of annual rainfall cover most of Baja California, the western part of Sonora, and the lowest parts of Chihuahua and Coahuila. The fluctuations of total rainfall from year to year are greater

in desert than in moister regions. At San Juan de Guadalupe, Durango, the ratio of the highest annual rainfall to the lowest in the past 20 years is 12.1. At Mulege, Baja California, the highest rainfall in the same period was 329 mm. and the lowest 1 mm. The duration of rainless periods is 6 to 7 months at several localities in the Chihuahuan Desert, 7 to 8 months on the Gulf coast of Sonora and Sinaloa, and from 11 to 18 months in Baja California. The variability of desert rainfall and the protracted rainless periods are the most important feature of the climate for vegetation, with resulting importance to the animal life.

The seasonal distribution of rainfall in northern Mexico shows wide geographical differences. On the Pacific coast of Baja California it is confined to the late winter; in Arizona and Sonora it is biseasonal; in the great plateau basin of Chihuahua and Coahuila the summer rainfall is high in some localities and very low in others, but the winter rainfall is low in all parts of the area. In the arid bushland of northeastern Mexico the rainfall is more generous and more evenly distributed. On the west coast of Mexico the biseasonal rainfall of northern Sonora merges gradually into predominantly summer rainfall in the Thorn Forest region of Sinaloa. These features of seasonal distribution control the activities of the vegetation. As the general climatic pattern has probably changed little during a long period of geological time, strong differences have developed in the floras of the areas involved.

## PALEOBOTANY

RALPH W. CHANEY

Because of the pressure of war activities, none of the group concerned with the program of Tertiary paleobotany has been

able to continue his studies effectively. Dr. Chaney has completed a study of an Eocene cactus which will be discussed in

a later report. He is spending a small amount of time regularly on large Middle Tertiary collections from the John Day Basin, and plans to submit for publication brief progress reports from time to time. Lieutenant MacGinitie's assignment in the Southwest is giving him an opportunity to make observations on the climate in this region which will be of value in his current study of the Florissant flora. Captain

Axelrod is reported to have been shifted from Australia to New Guinea, where it is hoped his close contact with tropical and subtropical vegetation may throw light on Eocene environments in western North America. Lieutenant Colonel LaMotte's supplementary catalogue of Mesozoic and Cenozoic plants of North America is now in final stages of printing after unavoidable delays since the beginning of the war.

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## DEPARTMENT OF EMBRYOLOGY

*Baltimore, Maryland*

GEORGE W. CORNER, *Director*

During the year 1943-1944 the national war effort, now at its height, has affected the work of the Department of Embryology more and more seriously. With two members of the regular staff of investigators and one Fellow away on wartime duty, practically no visiting workers in the laboratory, and the Director and others giving much time to emergency duties, naturally the pace of investigative work has slowed down. The collection of embryos has grown as usual and received a number of important additions, especially of early human embryos. Dr. C. H. Heuser, Curator of the Embryological Collection, aided by the technical staff, has carried on the work of preparing, photographing, and modeling the more instructive of the newly acquired specimens. Such preparative work is itself a phase of the process of investigation when the material in hand is new to science. Publication of the remarkable series of human embryos of the second and third week obtained by Dr. A. T. Hertig and Dr. John Rock and other workers has proceeded at a satisfactory rate, as indicated by the detailed summaries below.

Studies on the physiology of reproduc-

tion in the rhesus monkey and other animals have gone forward on a small scale, limited by wartime conditions and also by the fact that the monkey colony and associated resources of the Department have been partly given over to research on an important emergency medical problem, in association with investigators of the School of Hygiene, Johns Hopkins University. Uncertainties as to the supply of monkeys and of help in the animal house are, however, likely to diminish in the future. The procurement of living opossums necessary for the work on experimental embryology has been stopped by the fact that skilled animal collectors are now all in the armed forces or in war industries. Our investigators in the two fields just mentioned had, however, accumulated reserves of preparations, notes, etc., with which they have been able to continue study and publication of results. Readers of the following pages will observe, indeed, that many of the publications cited represent observations and experimental data accumulated in past years; and yet some new work has been done in each branch of our regular program except in biophysics and biochemistry.

## HUMAN EMBRYOLOGY

### DEVELOPMENTAL HORIZONS IN HUMAN EMBRYOS

Doctor Streeter's program of classification of human embryos by developmental stages, explained in Year Book No. 42, continues to advance. Last year Dr. Streeter published, in volume XXX of the Contributions to Embryology, the descriptive

matter and tables relating to his stages XI and XII. Stages XIII and XIV are in process of publication, and stages XV and XVI are well in hand. The work, when completed, will form an authoritative description and classification of human embryos by stages of growth, a catalogue of early embryos in the Carnegie Collection, and a guide to world material.

Stages XI and XII include embryos of 13 to 20 somite pairs and of 21 to 29 somite pairs respectively. In stage XIII, next to be considered, the full complement of somites is reached. The embryos are about 4 to 6 millimeters in greatest length. Arm buds are well defined and leg buds visible. The yolk sac communicates with the intestine by a slender stalk instead of a slit-like passage. The pore of the otic invagination is now closed; the lens vesicle is not yet indented. Even in the younger members of the group the blood circulation is well established throughout the embryo and the placental villi. The heart still lacks true valves, but, as Dr. Streeter points out, various local narrowings of the cardiac tube probably serve to prevent reflux of blood sufficiently to enable the myogenic contractions of the heart to move the blood. The age of embryos at this stage of development is estimated at  $28 \pm$  days.

In age group XIV, the most characteristic sign is indentation of the lens vesicle. Various stages of this process are seen, from a mere shallow pocket to a vesicle open to the surface only by a narrow pore. The embryos are about 5.5 to 8 millimeters long. The ear vesicle has a well defined endolymphatic appendage. The spinal cord remains tubular, but the brain, essentially tubular in earlier stages, now begins to exhibit ridges and thickenings which indicate the beginning development of its various special parts. In the digestive tract, Rathke's pouch becomes a prominent feature of the roof of the mouth. Transformation of the pharyngeal pouches into auditory tube and thyroid, thymus, and parathyroid glands is beginning. The trachea becomes detached from the esophagus. The mesonephros is being organized. The age of embryos at this stage of development is estimated at  $29 \pm$  days.

#### VERY EARLY HUMAN EMBRYOS

In Year Book No. 41 we were able to report the acquisition through our Boston collaborators, Dr. A. T. Hertig and Dr. John Rock, of two human embryos younger than any previously known. One is no. 8020, believed to be  $7\frac{1}{2}$  days old, and the other is no. 8004, about  $9\frac{1}{2}$  days old. As was reported in 1942, these specimens were successfully cut into serial sections by Dr. C. H. Heuser. During the past year Dr. Hertig and Dr. Rock have completed their study of these remarkable specimens and the definitive description, with photographs and drawings prepared in the Department of Embryology, will appear in volume XXXI of the Contributions to Embryology.

The nature of these two embryos will be made clear by the diagrams printed herewith (fig. 1). In these sketches, A to C represent stages not yet seen in the human embryo; they are taken from a paper by Dr. G. B. Wislocki and Dr. G. L. Streeter on the implantation of the rhesus monkey, in Contributions to Embryology, volume XXVII. They show how the hollow blastocyst, at first free in the uterine cavity, settles against the lining of the uterus, where a thickened part of the wall (*trophoblast*, solid black in the diagram) invades the uterine epithelium. It is necessary to suppose that the human embryo passes through stages much like these, during the first week after conception. Figure 1D represents a section of one of the new human embryos, no. 8020. It will be seen that it has burrowed more deeply into the uterus than does the early monkey embryo, and that the trophoblast is already spreading into the connective tissue below the surface. At one point (shown as a club-shaped channel at the right) the trophoblast has surrounded a small maternal blood vessel.

This embryo, as first seen by Hertig in a uterus removed surgically by Rock at the Free Hospital for Women, Brookline, showed itself as a tiny oval plateau about  $0.42 \times 0.46$  mm., slightly elevated above the endometrial surface. The chorion (i.e., the whole embryonic mass) measures 0.125

two tiny clefts, one of which is continuous with the chorionic cavity. The endoderm is represented by a few cells forming a caplike mass (schematically shown in the diagram as a thin black layer) applied to the ventral surface of the ectodermal embryonic disk.

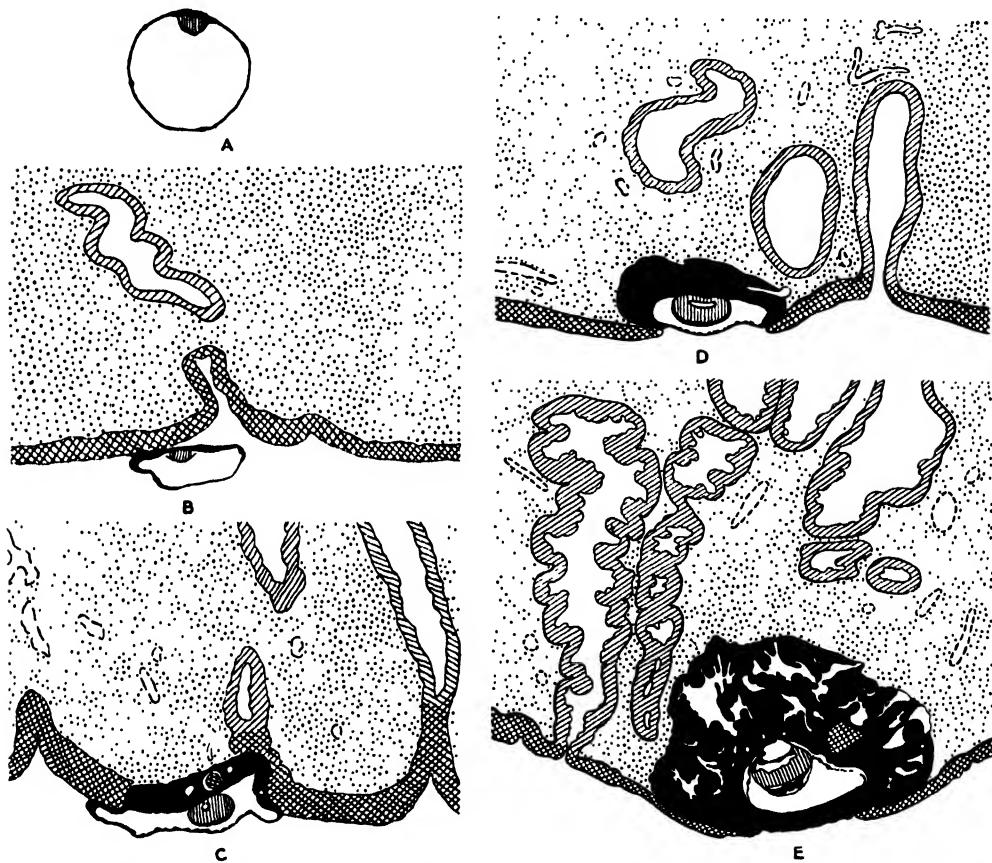


FIG. 1. Diagrammatic sections illustrating the attachment of the early primate embryo, as explained in the text.

$\times 0.300 \times 0.450$  mm. An ordinary pinhead is roughly three times this size. It will be noted that the blastocyst is flattened so that the thin uncovered part of its wall lies close to the inner cell mass. Such a collapse is seen in comparable rhesus monkey embryos and in slightly older human embryos. The amniotic cavity consists of

Diagram E represents the embryo of about  $9\frac{1}{2}$  days, no. 8004. The uterine epithelium has crept over the embedded embryo, almost covering it. The chorion now measures  $0.310 \times 0.450 \times 0.582$  mm. The invading part of the trophoblast has increased in thickness and has formed within itself a number of cavities (lacunae) which

contain blood from eroded maternal blood vessels. The amniotic cavity is now quite distinct, and the main part of the inner cell mass forms an oval embryonic disk measuring  $0.100 \times 0.132$  mm. This disk as yet bears no indication of axial differentiation. Inside the chorionic cavity a few mesoblastic cells are seen. The endoderm is scarcely advanced, in this embryo, beyond the stage seen in no. 8020.

The chief deductions from these embryos and from others of closely similar age, now in the collection but as yet unpublished, are that the human embryo probably implants on about the 6th day; development of the trophoblast is precocious and implantation by burrowing into the endometrium is rapidly achieved; the amnion seems to be formed as a cavity between primitive trophoblast and embryonic ectoderm.

Both these embryos are classifiable in Dr. Streeter's stage IV, implanting ova.

#### A PRE-VILLOUS EMBRYO ABOUT THIRTEEN DAYS OLD

Last year Dr. Andrew A. Marchetti, of Cornell University Medical College, discovered, in a curettage specimen from the New York Hospital, evidences of an early embryo. Fortunately only one-fourth of the chorionic wall was cut away in making the routine sections for pathological examination, and the rest of the block, rescued by Dr. Marchetti, contained the embryo, the amnion, and the yolk sac. He has studied and described the specimen with the aid of models and photographs made in the Carnegie laboratory. The trophoblast is well differentiated, with distinct lacunae, but the primitive villi have not yet definitely appeared. The extraembryonic mesoblast is excessive in amount and practically fills the chorionic cavity. Because of this fact, and of signs of mild inflammatory

reaction in the endometrium at the site of implantation, Dr. Marchetti believes his embryo is atypical. Thanks to recent acquisitions, including this and other early embryos, the Carnegie Collection now contains about as many atypical and abnormal embryos of the first three weeks as normal ones, and thus material for study of the earliest pathology of the human embryo is rapidly accumulating.

#### TWO EMBRYOS OF THE EARLY VILLOUS STAGE

Dr. C. H. Heuser has prepared in collaboration with Dr. A. T. Hertig and Dr. John Rock a full description of two embryos of the Hertig-Rock series. These have not previously been referred to in our reports; they are no. 7801, about  $13\frac{1}{2}$  days old, and no. 7802, about  $16\frac{1}{2}$  days old. The younger of these is covered with villi up to 0.25 mm. long. It shows an early stage in the development of the body stalk, represented by a condensation of mesoblast at the caudal end of the germ disk. The germ disk is oval, with diameters measuring about  $0.22 \times 0.25$  mm. The primordium of the primitive streak is recognizable, marking the appearance of axial arrangement of bodily structure. The yolk sac is nearly spherical, and has a bilaminar wall.

Embryo no. 7802, about 3 days older than that just described, is enclosed in a chorion which is covered with branched villi reaching a length of 0.5 mm. The germ disk measures  $0.35 \times 0.42$  mm., and shows a primitive node and a primitive streak 0.11 mm. long. This is the youngest embryo yet known in which the primitive node is present. The head process is identifiable. There is a well marked amniotic duct. An allantois is present. Both these specimens have relatively small yolk sacs separated by a considerable space from the inner wall of the chorion.

Dr. Heuser lays particular stress on the presence of cell-lined vesicles on and about the yolk sac. Such vesicles have been seen in other human embryos of the second and third weeks. He suggests that they represent transient survivals of tissues forming part of the large primary yolk sac which occupies most of the chorionic cavity at about the 12th day of development. He supposes that as the smaller definitive yolk sac is formed, detached vesicles of the primary yolk sac are left behind and are likely to be found in embryos of ages ranging from about 13 days to 2½ weeks.

#### AN EMBRYO OF ABOUT SIXTEEN DAYS

An embryo intermediate between the two just mentioned has been described by Dr. Karl M. Wilson. It was found in a curettage specimen obtained in his clinic at Strong Memorial Hospital of the University of Rochester. By good fortune all of the embryo except a very small portion at the caudal end was found in that part of the block which had remained uncut when the routine sections were made for pathological study. The chorion is covered with villi just beginning to branch. There is a well defined amniotic duct. The embryonic shield measures  $0.22 \times 0.31$  mm. It bears a recognizable primitive streak. In describing this specimen Dr. Wilson remarks that it shows particularly well the delamination of cells from the cytotrophoblast layer of the chorion, forming mesodermal cells of the villi and chorionic membrane.

#### EMBRYONIC DEFECTS LEADING TO ABORTION

At a conference on problems connected with abortion of the human embryo, held by the National Committee on Maternal Health in June 1942, Dr. G. L. Streeter presented a review of the evidence that deficiency of the germ plasm is frequently

the cause of embryonic defects and of abortion of defective embryos. He referred to experiments he conducted some years ago with Dr. E. A. Park and Dr. D. Jackson, of Johns Hopkins Medical School, in which it was found possible to breed, by selection, two strains of rats which were respectively vulnerable and resistant to rickets when placed on a rickets-producing diet. This is an example of a defective condition carried in the chromosomes. As an example of a similar situation in man, Dr. Streeter presented from the Carnegie Collection the case of a pair of fraternal twins, which of course began their embryonic life in the same environment, but one went on to birth at term as a normal baby, whereas the other died at the 20th week of gestation and was retained in utero and expelled with its normal companion. In such a case the difference in viability must have been inherent in the embryos themselves.

Another specimen from the Carnegie Collection cited in the discussion was a rhesus monkey embryo recovered 12 days after conception, which had reached only a 9 days' stage of development and showed deficient formation of the trophoblast. In this case some inherent incapacity had affected the attachment tissue, and would inevitably have produced abortion. Dr. Streeter went on to cite various examples of localized defects in human embryos ascribable to inherent genetic deficiencies.

#### RECOVERY OF EARLY EMBRYOS AND THE TIME OF OVULATION IN THE RHESUS MONKEY AND MAN

Since leaving us in 1941 to become professor of zoology in the University of Illinois, Dr. Carl G. Hartman has continued to bring out, from time to time, the results of previously unpublished work done in our Department. During the present year he has printed three lectures

given in 1943 in San Francisco. Two of these will be mentioned below, under the heading "Reproductive organs." The other concerns the recovery of primate eggs and early embryos, and deductions therefrom as to the time of ovulation with respect to the menstrual cycle. It covers a good deal of the history of this problem, both scientific and personal, as developed in the Department and elsewhere, and although much of the factual material has already been published, the lecture is a valuable and entertaining résumé of a complex subject. Dr. Hartman discusses the diagnosis of ovulation in the monkey by palpation of the ovaries, the technical methods of recovering eggs from oviducts and uterus, and the recovery of attached embryos. From the data of Hertig and Rock, Allen and Pratt, and W. H. Lewis, Hartman calculates that the average time of ovulation in man is day 15 after the onset of menstruation. The extremes in 19 cases were day 12 and day 21. He then reviews the whole of his own experience with the rhesus monkey, and shows that ovulation occurs between day 8 and day 16, with the mode on day 13.

#### DIFFUSION AND POPULARIZATION OF RESULTS

The Director of the Department of Embryology was invited to present the 1944 series of lectures on the Dwight H. Terry Foundation at Yale University. Since these lectures are intended to review what has been learned in various branches of science for the benefit of those interested, as the founder put it, in a broadened and purified religion, an opportunity was thus provided to summarize recent advances in human embryology for the general university audience and to point out the contributions of that science to the general problem of man's nature. The lectures dealt with (1) the normal early human embryo as an archive of evolutionary history and as a living individual, (2) the nature and causes of embryonic defects and prenatal death, and (3) evidence from embryology as to the position of man in the animal kingdom. In all three lectures, Dr. Corner naturally referred extensively to the work of the Department of Embryology and to many of the individual embryos in the Carnegie Collection. The Terry Lectures for 1944 will shortly appear in book form under the title "Ourselves unborn."

### EXPERIMENTAL EMBRYOLOGY

#### DIFFERENTIATION OF THE PHALLUS IN THE OPOSSUM

As previously explained in these annual reports, the reproductive habits of marsupials such as the opossum provide the embryologist with the opportunity to do experimental work on mammals in embryonic stages. In the higher (Eutherian) mammals, in which the embryos are borne in the uterus, they can only be reached for experimental purposes with great difficulty and risk of abortion or resorption; but in marsupials, which bear the young in a brood pouch after the first 12 days or

thereabouts, the young are easily gotten at in embryonic stages. Dr. R. K. Burns' program of research in this field progresses actively. In the forthcoming volume of Contributions to Embryology he reports work on the differentiation of the phallus and its reactions to sex hormones. In a paper published five years ago, Dr. Burns showed that sex hormones have the power to determine the external form of the phallus; the present paper covers a larger series of experiments and especially aims to explain the changes in external form in terms of the constituent tissues. It includes

a detailed description of the histology of the phallus. Under the influence of sex hormones administered to the pouch young from the time of birth (12½ to 13½ days after conception) until the 25th day of pouch life or later, the tissue components of the phallus react in a highly specific manner, producing an organ which in configuration and internal structure is of distinctly male or female type in accordance with the hormone that is acting. This modification occurs with equal facility in embryos of either sex, only quantitative differences appearing. Its basis is found in the specific way in which the histological components respond to the appropriate hormone. The erectile tissues and the phallic part of the urethral apparatus react positively to male hormones (androgen) in both sexes, by growth and precocious differentiation. The sum of these changes confers upon the organ its specifically male form. The effects of female hormone (estrogen) are both positive and negative (inhibitory). There is hypertrophy of the urinogenital sinus, accompanied by proliferation and cornification of the epithelium and increase in diameter of the canal. The erectile tissues, on the contrary, are inhibited. It thus appears that the characteristic dimorphism of the phallus imposed by the two types of hormone is not a simple or unitary response of the organ as a whole, but is determined by distinct and inherent reactions, some positive and some negative, on the part of the various histological components, to the respective hormones.

#### EFFECTS OF MALE HORMONE ON DIFFERENTIATION OF THE URINogenITAL SINUS

In two papers published in 1939 Dr. Burns described the effects of sex hormones in modifying the early development of the urinogenital sinus and its derivatives in the

opossum. These accounts dealt largely with modifications of the form of the organs involved, but a more recent paper, mentioned in Year Book No. 42, described the effects of the estrogenic hormones on the histological structure. Dr. Burns has this year continued his discussion to cover the effects of androgenic hormone on the histology of the urinogenital sinus and its derivatives. The findings are best understood if we recall that in the opossum division of the urinogenital sinus from the rectal part of the cloaca is complete at birth; thereafter, the differentiation of the embryonic sinus into male and female types occurs gradually, and is essentially complete in pouch young of 50 days. In males the sinus gives rise to the urethra and the prostate gland complex. In females the proximal part of the sinus, including the sinus horns, gives rise to the greater part of the lateral vaginal canals, and to the urethra, and the distal part becomes the adult urinogenital sinus. There are absolutely no prostatic rudiments at any stage of normal female development.

When androgens are administered to male pouch young, the result is acceleration of the normal process of differentiation, without essential alteration of the male form. In females receiving androgenic hormone the anatomical form of the sinus is greatly modified. The sinus horns usually fail to migrate and form lateral vaginal canals, and the vaginal outlets do not assume the definitive female position. Growth of prostatic tissue is induced and proceeds to a degree far in advance even of normal male development. At 50 days the masculinized female urinogenital sinus is scarcely distinguishable from that of a treated male littermate except for a minor quantitative difference in size.

As in the case of the phallus, it appears that the responses of the tissues of the urinogenital sinus are specific for the type

of hormone acting, in keeping with the principle that parts or tissues which undergo definitive differentiation in a given sex react positively by growth and development to the appropriate type of hormone; whereas parts proper to the opposite sex either fail to react, or are actively inhibited in their development. Paradoxical effects,

violating this principle, are ascribable to dosage of the hormones beyond physiological limits. Dr. Burns discusses, but leaves open for the present, the question as to whether the estrogenic and androgenic hormones, or nearly related substances, take part in the normal differentiation of sex.

## THE REPRODUCTIVE ORGANS AND THEIR HORMONES

### THE VAGINAL CYCLE

The description by Stockard and Papanicolaou, in 1917, of a very strongly marked series of histological changes in the vagina of the guinea pig under the influence of the ovarian cycle gave the impulse to a great advance in our knowledge of the reproductive cycle in mammals. Their observations, and similar studies on the rat and mouse, led directly to such discoveries as the identification of the estrogenic hormones and the isolation of vitamin E. It was to be hoped that what had been learned from the small laboratory rodents could be applied to the human species, making possible an analysis of the human cycle, enabling the accurate diagnosis of ovulation, and in these and other ways solving many problems of human physiology and disease. Although it is difficult for many reasons to subject normal humans to study of the vaginal cycle, such studies could be undertaken on patients suffering with disturbance of the reproductive system. Results obtained in the gynecological clinics were, however, disappointing as far as the study of the normal human cycle was concerned. The same was true of efforts to study the vaginal cycle of the rhesus monkey, made by Hartman and Corner in their respective laboratories. In both human and rhesus monkey it was found that in a general way the cells seen in vaginal washings or scrapings undergo cyclic changes of the same general

type as those of the rat, mouse, and guinea pig, but so much less strongly accentuated that vaginal smears could not be used practically for following the cycle. Gross changes of vaginal structure, such for example as those produced by massive doses of estrogenic hormones, or by ovarian deficiency after menopause or surgical removal of the ovaries, could easily be detected by vaginal smears and the information thus gained could even be used to control treatment with hormones; but the slighter variations occurring in the normal cycle were very obscurely reflected in the vaginal smears.

In 1933, however, Papanicolaou published an important study of the human vaginal cycle based on a greatly improved technique. Clinical workers, including especially Ephraim Shorr of Cornell Medical College, were able to use the new method for diagnostic purposes and valuable results were obtained. It seemed desirable therefore to re-examine the cycle of the rhesus monkey by the new technique and to compare results with those obtained in women. This work was undertaken in 1941 by Dr. Inés de Allende, of Córdoba, Argentina, who was at the Department of Embryology as a Rockefeller Fellow. The work was begun in consultation with Dr. Hartman, who was then still with us, and was continued by Dr. de Allende in Dr. Shorr's clinic at the New York Hospital. The result was a cooperative study, finally

described in a joint paper, with introduction by Dr. Hartman and descriptions of the monkey's cycle and that of the human by Dr. de Allende and Dr. Shorr respectively. The colored illustrations necessary in work of this kind have been reproduced in two superb lithographic plates by A. Hoen and Company from drawings by Dr. Shorr and Dr. de Allende, and from Kodachrome microphotographs by Mr. Chester Reather.

Because of the improved discrimination of phases in the history of the epithelial cells, made possible by Shorr's modification of Papanicolaou's staining method, it has been possible to relate the primate cycle, as seen in the two species studied, to the vaginal cycle as learned from the rodents, more closely than before. A mid-interval peak of epithelial desquamation was found by direct experiment in the monkey to be related to ovulation. Criteria for detecting anovulatory cycles in both species were worked out. Changes produced by administration of hormones were described. Most important of all, the demonstration of a fundamental similarity between the vaginal secretions of the two species, not only during the menstrual cycle but under the influence of hormones administered experimentally, promises that studies on the monkey will contribute to the solution of difficulties in interpretation of human vaginal changes.

#### STRUCTURE OF THE CORPUS LUTEUM OF THE RHESUS MONKEY

Detailed study of the microscopic structure of the corpus luteum is of interest from several standpoints. In the first place, it provides a unique opportunity to observe the rebirth, from cycle to cycle, of an important organ of internal secretion. The manner in which the small lining cells of the ovarian follicles are converted

into large secretory cells, provided with a net of blood vessels and with supporting connective fibers, and thereafter even more suddenly reduced again to low estate, cannot fail to awaken the interest of the histologist. In the second place, the study raised many physiological questions. How quickly is the corpus luteum organized? When does it begin to function as an endocrine gland? What is the temporal relation between its regression and that of the uterus, and—in the primates—the onset of menstruation?

In the third place, accurate information about the structure and appearance of the corpus luteum from day to day will enable us to understand the relation of defects and retardation of the corpus luteum to pathology of the early embryo.

Dr. George W. Corner, in collaboration with Dr. Carl G. Hartman, formerly of this Department, and Dr. G. W. Bartelmez, of the University of Chicago, has completed a detailed account of the organization and breakdown of the corpus luteum in the rhesus monkey. The work is based on corpora lutea and accompanying uterine tissues and physiological data accumulated during the past twenty years and more by the three collaborators and by Dr. H. B. Van Dyke. Specimen slides of all of these and complete serial sections of many, together with sections of the uteri, have been assembled at the Carnegie laboratory. No such collection of dated ovaries, accompanied by uteri, embryos, and other relevant material, exists for any other primate.

The details of the descriptive report thus worked out need not be cited here, except to say that there is a regular progression of events as the granulosa cells enlarge and the lutein wall is vascularized. By use of the characteristic changes thus brought about, it is possible to determine the age of a corpus luteum from day 1 to

day 13, within limits of  $\pm 1$  day, by microscopic examination. Organization of the corpus luteum is completed about day 8, and the first definite signs of degeneration are seen about day 13 after ovulation, at which time it is possible to recognize a stage of the corpus luteum corresponding to Bartelmez' phase of premenstrual involution of the endometrium. Progressive degenerative changes characterizing the time of menstruation are fully described.

If the animal becomes pregnant, the corpus luteum does not degenerate, but retains its 12th-day characteristics until about the 19th day, when it begins a transition to the pregnancy type previously described by Corner, Bartelmez, and Hartman (Amer. Jour. Anat., vol. 59, 1936). After day 24 it is in the typical pregnancy stage.

The bulk of the lutein tissue is derived from the granulosa cells, but in this species the theca interna cells retain their identity after ovulation and persist at or near their original situation, about the periphery of the corpus luteum and in the bases of the folds produced by collapse of the follicle. After day 4 they are for a time indistinguishable from the granulosa cells, but they are sometimes again visible after day 6; and their invariable return to visibility in the corpus luteum of pregnancy and in the corpus aberrans indicates that they retain their identity even when not distinguishable in ordinary microscopic sections. It should be added that in preparing the descriptions, emphasis has been laid upon those features which can be seen in ordinary sections stained with haematoxylin and eosin. It should be readily possible, therefore, for gynecologists and other students of the human ovary to make direct comparisons. Observations of human corpora lutea which have incidentally come to Dr. Corner's notice show a strong resemblance in detail between the develop-

mental stages of the human corpus luteum and those of the rhesus monkey. A diagnosis of the age of a human corpus luteum in days after ovulation, made on the basis of criteria set forth in this paper, will probably be approximately correct. The article is illustrated by a set of microphotographs especially chosen to show general structure as well as fine details, and to facilitate comparison with other species.

#### ABSORPTION OF STEROID HORMONES FROM THE ORAL MUCUS MEMBRANES

Dr. George W. Corner, Jr. (captain, Medical Corps, U. S. Army), during a few months spent in the Department as guest investigator, undertook to test the possibility of administering the corpus luteum hormone, progesterone, by absorption through the mucous membranes of the mouth, i.e., by placing small quantities of the hormone, dissolved in a water-miscible solvent of low surface tension, such as propylene glycol, on the floor of the mouth beneath the tongue. Such a method of administering steroid hormones, of the estrogen, androgen, and corticosterone series, has been on trial for several years. It has the great advantage of avoiding repeated puncture of the skin by hypodermic needles. The more obvious method of administration through the mouth into the stomach is not practical with these substances because of partial or complete loss of activity while passing through the digestive canal and liver. Dr. Corner's review of the literature showed that in clinical trials estrogens are as effective sublingually as by intramuscular injection, whereas desoxycorticosterone, various androgens, and pregneninolene require about fourfold larger doses by sublingual than by intramuscular administration.

He then made a series of tests with castrated female rhesus monkeys, using a tech-

nique of assay worked out by G. W. Corner, Sr., in which the test is the power of the progesterone to inhibit the uterine bleeding which follows discontinuance of a course of estrogen injections. Another series of tests was made on rabbits, using the standard method of assay of progesterone described by Corner, Sr., and W. M. Allen. Results were somewhat variable, partly no doubt because of the difficulties in applying this method of drug administration to experimental animals. In both series of experiments, however, clear evidence was obtained that the progesterone was absorbed, and in each the minimum dose necessary to elicit characteristic effects was found to be about four times that required by subcutaneous injection. If and when the cost of progesterone permits, the sublingual route may find a useful place in clinical practice.

#### OVARIAN ADHESIONS IN THE RHESUS MONKEY

Dr. Carl G. Hartman has published an interesting account of observations on ovarian adhesions, made while he was actively studying the physiology of reproduction in rhesus monkeys in this laboratory. In the course of numerous abdominal operations on female monkeys, Hartman noticed in more than two dozen cases threadlike strands of tissue connecting the omentum or the fringes of the Fallopian tube with the ovary. In many of these cases it was ascertained that the adhesion arose from the stigma of a recently ruptured follicle or from the ovarian surface over a corpus luteum. He presents evidence, illustrated with striking photographs by Mr. Chester Reather, indicating that the adhesions are formed by the viscous and tenacious liquor folliculi issuing as a thread from the rupture point of a follicle. In four cases such threads were

found within a day or two of the time of ovulation, when they were still hyaline and tinged with red from blood dissolved or suspended in their substance. Evidently this semiliquid material becomes attached to the omentum or other contiguous structure, and is finally invaded and organized by connective-tissue cells. The resultant strand is slender (1 mm. or less, down to hairlike thinness) and often very strong. Adhesions of this type known to be as old as 70 days have been seen. Whether or not ovarian adhesions in human patients ever arise in the same way is not known.

#### THE NORMAL AND THE HYPERACTIVE OVARY

In one of his San Francisco lectures of 1943, referred to above, Dr. C. G. Hartman presents a discussion of experimental work on animals, especially primates, which may assist gynecologists in analyzing the problems of ovarian function. Much of the work described was done in this laboratory. The lecture deals with too many details to be abstracted here. One of the important points emphasized is that the production of hyperplasia of the uterus by overaction of estrogenic hormone depends not so much on the amount of hormone given as upon continuity of administration. Hartman discusses also the relation of cysts of the ovary to hyperplasia; he shows that in monkeys ovarian cysts often do not disturb the menstrual cycle, and suggests that there is danger of confusing cause and effect in theorizing about this problem on the basis of clinical observations.

#### REGENERATION OF THE ENDOMETRIUM

In a third of his 1943 lectures, Hartman reports upon the ultimate effects of complete removal of the endometrium of the rhesus monkey by hysterotomy, done in order to obtain early embryos. All the

experiments were carried out in this Department. The technique of the operation, which will greatly interest investigators of primate embryology, is carefully explained and illustrated by four exceptionally clear drawings by Mr. J. F. Didusch. The endometrium is dissected out as a sac and is almost completely eliminated, as a tissue, from the uterus. Dr. Hartman shows that this drastic operation is followed by rapid healing and regeneration

of the uterine lining. In one case the endometrium was completely reconstituted in 16 days. Another monkey successfully conceived again, 13 days after such removal of the endometrium when pregnant with a 10-day embryo. One animal regenerated the endometrium after four hysterotomies. Several passed the most crucial test of recovery by bearing infants to term after previous ablation of the endometrium.

### EXCHANGE OF SUBSTANCES BETWEEN THE BLOOD AND SURROUNDING TISSUES

#### TRANSFER OF SODIUM ACROSS THE HUMAN PLACENTA

The annual report of this Department in Year Book No. 41 contained a summary review of studies on the transfer of substances through the placenta, conducted by Dr. Louis B. Flexner, Dr. Herbert A. Pohl, and Dr. Alfred Gellhorn. At that time of writing Dr. Flexner's group, which was being dispersed by the war emergency, had in progress an investigation of the transfer of sodium across the human placenta at various stages of pregnancy. Eleven observations were made, and although these form a not entirely adequate series, they are unique and were obtained only after considerable effort and expense. The authors (Dr. Gellhorn, Dr. Flexner, and Dr. Louis M. Hellman, of the Department of Obstetrics, Johns Hopkins University) have now published them.

The observations were made on women in whom pregnancy was terminated by abdominal operation, for grave medical reasons as indicated in the report. In each case, about 30 minutes before operative delivery a small amount of radioactive sodium in the form of  $\text{Na}^{24}$  in solution was injected into an arm vein of the mother. The amount of radioactivity in-

volved is known to be innocuous to mother and fetus. In those cases in which the fetus was too young to be viable, its tissues were subjected to direct measurement of the radioactive substance which had reached it. When the fetus was viable, a sample of blood was taken from a vein and its radioactivity measured.

Calculations from the data obtained permit two tentative conclusions. In the first place, there is an increase in rate of transfer per unit weight of placenta as gestation advances. The over-all increase, between the ages of 10 and 38 weeks, is 7 times. A similar increase has been observed in all species previously studied (pig, goat, cat, guinea pig, rat, rabbit). In the human it can be related to morphological changes which occur as the placenta ages; namely, an increase in the number of the placental villi and in their total surface area, disappearance of the cytotrophoblast or Langhans layer of cells (the inner of the two cell layers originally clothing the villi), and an increase of blood capillaries in the villi together with thinning of the capillary walls. The sum of these changes provides an explanation of the increase in transfer rate per unit of placental tissue.

The other conclusion is related to the fact (explained in Year Book No. 41)

that the placentas of the various mammals differ greatly with respect to the number of cell layers interposed between the maternal and the fetal blood streams. The human placenta belongs to the hemochorionic type, in which the maternal cell layers are abolished and maternal blood comes into direct contact with the surface of the fetal element, in this case the placental villi. It appears from the present work that the rate of transfer of sodium per gram of placenta per hour in man is closely like that reported by Flexner, Gellhorn, and Pohl for other hemochorionic placentas (rat, rabbit, guinea pig) at corresponding stages of gestation.

#### TRANSFER OF WATER ACROSS THE PLACENTA OF THE GUINEA PIG

Dr. Flexner and Dr. Gellhorn have used heavy water as an indicator of the passage of water through the placenta of the guinea pig.  $D_2O$  was injected into the pregnant animal and at a standard interval thereafter the fetuses were removed. The water from the maternal blood and from the fetuses was recovered by distillation and the proportion of heavy water ascertained by a specific gravity method. In this way the rate of transfer of water was studied from the 28th day of pregnancy until the end of gestation. The rate of transfer per unit weight of placenta increases about 9 times during this period. The results with heavy water satisfy the hypothesis, previously advanced with respect to sodium, that the fundamental principle underlying placental transfer is that the rate of transfer to a unit weight of fetus parallels the relative growth rate of the fetus. In the early stages of gestation the fetus received about 150 times as much water, and in the later stages about 500 times as much, as is incorporated in the growing tissues.

#### TRANSFER OF WATER AND SODIUM TO THE AMNIOTIC FLUID OF THE GUINEA PIG

Using sodium and heavy water as tracers, by methods described in the papers previously discussed, Dr. Flexner and Dr. Gellhorn studied the rate of transfer between the maternal circulating blood and the amniotic fluid at the end of the first third of pregnancy, and observations were made from that stage until the end of gestation. The experimental results showed that the rate of delivery of water to the amniotic cavity is such that a volume of water equal to the volume of the amniotic fluid is exchanged, on the average, about once an hour at all periods of gestation examined. The rate of transfer of sodium is on the average about 50 times less rapid than that of water.

#### EXCHANGE OF WATER BETWEEN THE BLOOD AND THE EXTRAVASCULAR FLUIDS

In the course of the extensive studies on transfer of substances across the placenta referred to in the preceding paragraphs, Dr. Flexner and his collaborators found it necessary to investigate certain general problems of exchange between the blood and the extravascular fluid (i.e., all the fluid in the tissues and tissue spaces of the body, except that in the blood vessels). Heavy water (deuterium oxide), for example, was used as a tracer substance in studying placental transmission; to enable complete understanding of the results, it became necessary to study the rate of movement of water between the blood vessels and the fluids of the tissues of the body, in nonpregnant animals.

In a paper published in 1942, but not previously cited here, Dr. Flexner and Dr. Gellhorn, aided by Dr. Margaret Merrell, of the School of Hygiene and Public Health, Johns Hopkins, describe the movement of heavy water injected into the

blood vessels of the guinea pig. A measured quantity of isotonic salt solution, made up with water containing a known proportion of heavy water ( $D_2O$ ), is injected into a vein. The original concentration of DHO thus produced in the blood, just after the injection, is calculated from the amount of water in the animal's blood, as determined by estimation from available data. Thereafter, as water passes through the walls of the blood capillaries into the tissues and vice versa, the DHO becomes mixed with the ordinary water of the extravascular part of the body as well as with that of the blood, until the proportion of DHO is the same inside and outside the blood vessels, i.e., equilibrium is attained. Blood samples taken during this process of adjustment show, of course, a drop in the proportionate quantity of DHO in the blood, at first rapid, then slower and slower until equilibrium is reached. If the concentration present in the blood after each successive one-minute interval is plotted on a graph, it becomes possible by mathematical analysis to calculate the rate at which water within the vessels exchanges with that outside them.

The results show that equilibrium is reached very quickly, in fact in about 9 minutes. Calculations show that in the guinea pig 73 per cent of the water in the blood is exchanged with extravascular water every minute. Readers not familiar with such problems may be aided in visualizing this surprisingly fast movement by imagining two dense crowds in a subway station, passing through the turnstiles so

fast that three-fourths of the people on one side pass through the stiles and are replaced by an equal number from the other side within one minute. Many gates would be needed to permit such rapid passage; and likewise it appears that the walls of the smaller blood vessels, in spite of their power to hold back blood cells and even large molecular masses, are veritable sieves with regard to water.

#### EXCHANGE OF SODIUM

The same authors (Merrell, Gellhorn, and Flexner) have now reported on the rate of exchange of a salt between the blood stream and the extravascular fluid. The tracer element used was radioactive sodium ( $Na^{24}$ ). The method of experiment and the mathematical analysis were similar to those used in tracing the movement of heavy water. Equilibrium is reached in less than 10 minutes. It is found that 67 per cent of the diffusible sodium in the blood plasma moves outward and 13 per cent of the sodium of the extravascular fluid is transferred into the plasma per minute. The amount of water relative to that of sodium crossing the vascular wall per minute is about twice what would be expected from their respective concentrations in the plasma. In other words, the walls of the vessels are about twice as permeable to water as to sodium. It will be evident that this method permits a description of the vascular system in terms of its relative permeability to all substances which can be identified by isotopes.

#### TUMOR STUDIES

##### A SARCOMA-PRODUCING EXTRACT

A number of investigators have reported the extraction of tumor-producing substances soluble in fat solvents from human tumors and from the livers of human be-

ings afflicted with neoplasms. The injection of the extracted fatty compound into rats and mice, however, produced tumors in only a small percentage of the treated animals.

Dr. Margaret R. Lewis of our staff, working at the Wistar Institute of Anatomy and Biology in Philadelphia, and Drs. P. M. Aptekman and Helen Dean King, of the Wistar Institute, have followed this lead by making extracts of tumors occurring in rats, and injecting them into rats of the same strain. It was thought that the extracts may be more effective when they come from tissues having the same biological characteristics as those of the recipient test animals.

The tumors extracted were sarcomas (malignant neoplasms of connective-tissue type) that had been produced experimentally by administering carcinogenic hydrocarbons to inbred albino rats of Dr. King's well known Wistar colony. These rats do not often develop tumors spontaneously. Autopsy of 200 untreated rats 10 to 12 months old revealed no tumors. The strain is, however, 100 per cent susceptible to carcinogenic chemical substances and to the growth of ingrafted tumors of the kind used in the experiments.

An extract of the rat tumors made with benzol was injected into 28 young rats. Two injections at intervals of 4 months were given. Six months after the second injection 5 rats had developed sarcomas at the site of injection. Tumor tissue from 3 of these was transplanted into other rats and proved to be capable of repeated transmission.

Twenty-four rats were similarly injected with a benzol extract of livers of rats bearing transplanted sarcomas. Two of them developed sarcomas at the site of injection.

One rat in each of these experimental groups developed carcinoma of the mammary gland.

The percentage of tumors thus induced in rats by extracts from tumors of animals of the same strain was slightly larger than that obtained by previous investigators who administered extracts of human tumors or

livers to rats and mice; but it was still small in proportion to the number of rats treated.

#### A RHABDOMYOMA IN TISSUE CULTURE

Dr. Warren H. Lewis has reported the results of a long study on the cellular characteristics of a malignant tumor of remarkable nature. The original tumor was found in 1920 in a rat at the Institute of Cancer Research, Columbia University, and was reported in 1922 by F. D. Bullock and M. R. Curtis in the *Journal of Cancer Research*. It was of the type known as chondro-rhabdomyo-sarcoma; that is to say, it contained cartilage cells, fibers of voluntary muscle, and less differentiated malignant cells of the kind seen in sarcomas. The discoverers kept the tumor tissue alive by rat-to-rat transplantations. After a few transfers the tumors developing from new transfers no longer contained cartilage cells, and after 13 years they ceased to contain striped muscle cells. The tumor tissue, as seen in sections, now had the appearance of a mixed-cell sarcoma. At this time Dr. Lewis began to maintain the tissue in our laboratory in tissue cultures, starting with cells obtained from a tumor, newly grown after transfer to a fresh rat, which contained no recognizable muscle nor muscle-like cells. After 3 to 6 months of growth in roller tubes, the cultures consisted of pure colonies of cells that gave rise, when again inoculated into rats, to tumors with "muscle giant cells," i.e., large multinucleated cell masses of a type approaching the structure of voluntary muscle fibers. After 13 to 20 months of culture *in vitro* the cells produced tumors but no giant cells. The interpretation of this interesting observation is that the malignant cells, which Dr. Lewis considers to be myoblasts (embryonic muscle cells), to which the tumor had reduced

itself during the long period of rat-to-rat transfer regained on cultivation in vitro and then again lost their ability to form muscle giant cells.

Both these investigations on tumors were aided by a grant to Dr. W. H. Lewis from the International Cancer Research Foundation.

## NUTRITION

### HEXOSES AND THE RESPIRATORY EXCHANGE IN MONKEYS

Several years ago Dr. Thorne M. Carpenter, of the Nutrition Laboratory of the Carnegie Institution, and Dr. Carl G. Hartman, then of the Department of Embryology, undertook to study the effects of hexoses on the respiratory exchange of rhesus monkeys. The investigation was part of the Nutrition Laboratory's general program of research on biological variations in the response of the respiratory exchange to ingested glucose, levulose, and galactose. The results will no doubt be discussed more fully in the report of the

Nutrition Laboratory. It will suffice to state here that in the rhesus monkey glucose caused the greatest rise in the respiratory quotient, fructose the next largest, and galactose the least. This means that the proportion of heat production supplied by carbohydrate varies according to the sugar burned, in the order named. In man, the order in this respect is fructose, galactose, and glucose. The specific dynamic action of these sugars (i.e., the percentage relation between the fuel value of the sugar and the increase in heat production) averaged 9 to 11 per cent, which is a little higher than in human subjects.

## COMPARATIVE ANATOMY OF PRIMATES

### AGE CHANGES AND VARIABILITY IN GIBBONS

The present year has seen the publication of a notable addition to the series of studies by Dr. Adolph H. Schultz, of the Department of Anatomy, Johns Hopkins Medical School, on the anatomy, growth, and variations of the primates. Dr. Schultz' work naturally stands in close relationship with the program of investigation of embryology of the primates which is one of the major interests of this Department. The present contribution was aided by a grant made by the Carnegie Institution toward Dr. Schultz' expenses as a member of the Asiatic Primate Expedition of 1937.

The report on the gibbons is based on 277 skeletons of various species, of which 233 represent *Hylobates lar* from the district of Chiengmai in Siam. All ages from fetal life to old age are represented. It is the largest group representing any one

anthropoid ape, or indeed any one primate species other than man and the rhesus monkey, to be subjected to systematic metric study. The specimens, in fact, constitute a "population sample" useful for study of age changes and the degrees of variability in this manlike ape. The gibbon is the only anthropoid ape which survives in numbers sufficient to provide statistically adequate material.

It is not possible to discuss here all the findings of Dr. Schultz, whose summary alone occupies ten pages. Some of the more generally interesting conclusions follow. Adulthood in gibbons is reached toward the end of the 9th year. The weight at birth is about 400 grams. The average body weight of adults is 5.3 kg. in females, 5.7 kg. in males. The ratio of birth weight to the weight of the adult female, 6.7 per cent, is the highest known among primates.

After detailing the changes in bodily proportions during growth and adult life, Dr. Schultz remarks that with few exceptions the bodily proportions of gibbons, spider monkeys, macaques, proboscis monkeys, orangutans, chimpanzees, and men are much more similar during fetal than during adult life. The variability of structure of gibbons, even within the geographically limited series from Chiengmai, is as great as that of individuals in average human series. The sequence of eruption of the deciduous teeth differs from that in the great apes, and agrees with that in catarrhine monkeys and man, in that the canines appear before the second molars. The sequence of eruption of the permanent teeth agrees with that characteristic of the

great apes, but differs significantly from that found in recent man.

Anomalies and malformations of the skeleton are frequent. One or more abnormalities in the skeleton and dentition occur in nearly half the individuals of the wild gibbons from Chiengmai. Pathological conditions in the teeth and bones become steadily more numerous with advance in age and exposure to the hazards of living. In a total of 104 senile gibbons, 55 had at least one diseased tooth or alveolus. In the Chiengmai series there were 115 healed fractures of bones. One individual succeeded in repairing seven fractures (jaw, fibula, and five ribs).

The article is illustrated with numerous vivid pen drawings by Dr. Schultz.

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## DEPARTMENT OF GENETICS

*Cold Spring Harbor, Long Island, New York*

M. DEMEREC, *Director*

Dr. Charles Benedict Davenport, organizer of this Department, its Director until his retirement in 1934, and Research Associate during the past ten years, died on February 18, 1944. With his death, the Department and our scientific community lost a member of outstanding qualities.

This Department was among the first to be established by the Institution. In 1902 Dr. Davenport was one of two biologists whose plans for research in biology were considered by the Trustees (Year Book No. 1, 1902). His plan was accepted, and in 1904 he was given an opportunity to organize a laboratory at Cold Spring Harbor. The new laboratory was named "Station for Experimental Evolution," and its main program consisted of studies in heredity, development, and evolution. All this happened only four years after the rediscovery of Mendel's laws, at the time when the new science of genetics was in its early formative stages. It is proof of Davenport's courage, and of the vision of the Trustees, that the program of the newly established laboratory dealt with problems which were at that time novel and untried. The young science of genetics was then passing through its first crisis. Biologists were unused to the quantitative methods and inductive approach to problems introduced by genetics; and it required considerable effort on the part of pioneers in the new science to accumulate experimental proof of the validity of its basic assumptions. Davenport was one of these pioneers. He made an important contribution to early genetics, not only through his own work and that of this Department, but also through the interest

in genetics which he helped to stimulate on the part of the Carnegie Institution. This resulted in substantial financial support for research, which came at a critical time and brought impressive returns. Many of the American pioneer geneticists were helped by grants from the Institution (among these, W. E. Castle, E. B. Wilson, T. H. Morgan, C. B. Bridges, A. H. Sturtevant, C. E. McClung, R. Pearl, H. E. Crampton, E. B. Babcock, H. D. Goodale, L. R. Dice, and F. B. Sumner); and it seems probable that this aid has contributed significantly to the development of genetics in the United States and has helped to establish genetic research in the leading position it now occupies.

During the year covered by this report the Department lost two other members through death. George Macarthur, superintendent of buildings and grounds, who had been employed by the Department since 1914, died on October 4, 1943; and Miss Alice M. Hellmer, artist and photographer with the Department since 1921, died on August 13, 1944. Both deaths came unexpectedly and were felt as a great loss to the Department.

On July 1 the resignation of Dr. Morris Steggerda became effective, when he took up his new position as professor of anthropology at the Kennedy School of Missions, a division of the Hartford Seminary Foundation. During the years he had spent at this Department, since June 1930, Dr. Steggerda had participated in work on a number of important research projects. He collaborated with Dr. Davenport in studies of race crossing in Jamaica, took part in investigations of Maya Indians in Yuca-

tan, and carried on anthropometric and anthropological studies among Navajo and Maya Indians, Dutch-American families in Michigan, and southern Negroes. It is expected that in his new position Dr. Steggerda will have many opportunities for extending these studies throughout a wider field.

Throughout this year several members of the Department were engaged in research related to the war effort. Potter spent full time on the cooperative project with the Biological Laboratory, under contract with the Chemical Warfare Service. In addition, Demerec took part in this work and MacDowell provided experimental animals from his mouse colony. Fano has been working part time since December 16, 1943, and full time since May 1, 1944, at the Ballistic Research Laboratory. Under a contract with the War Production Board, Demerec, San-some, and Warmke, with the help of several assistants, have carried on research related to the production of penicillin.

As a war emergency project, Warmke began in 1942, in cooperation with the Bureau of Plant Industry of the U. S. Department of Agriculture, an attempt to produce a strain of fiber hemp with reduced marihuana content. He now has several strains which differ in average marihuana content by a factor of nearly 4. The low-content strains are significantly less toxic than the parental stocks from which they were derived, and may be approaching a level where they would be of little value to the illicit drug traffic. In an effort to determine the site of synthesis of the marihuana drug in the hemp plant, grafts were made in which hop strains were joined to hemp roots at the ground level. It was found that in such combinations large quantities of the drug are synthesized and translocated into the normally nontoxic hop leaves. Warmke's

studies on the sex mechanism in hemp have revealed a new type of balance between male and female genes. The classes 3A XXY and 4A XXXY are female or female-hermaphrodite in hemp; in other forms studied, including *Melandrium* and *Silene*, these classes are male or male-hermaphrodite. Continuing investigations on sex in *Melandrium*, he obtained evidence from a study of spontaneous aberrations of the Y chromosome for at least two regions of major importance in the development of maleness. One of these regions appears to be near the centromere, and is responsible for the initiation of anther and filament primordia and for carrying male development through meiosis. The other is probably distal, and is responsible for the elongation of filaments and for the maturation of viable pollen grains. Warmke found also that experimental lots of tetraploid plants of the Russian dandelion have significantly heavier roots and a slightly higher rubber percentage than comparable diploids. Water content of the diploid and tetraploid forms does not differ significantly.

During this year McClintock completed studies of the 7 pale-yellow-seedling mutants and the 6 white-seedling mutants associated with small terminal deficiencies which arise independently following breakage of the short arm of chromosome 9 in maize. To determine the rate of production of these deficiency mutants, 3287 such chromosomes were genetically tested for the presence of the pale-yellow-producing deficiency or the white-producing deficiency. Seventy-seven of these gave rise to the pale-yellow phenotype, and 48 gave rise to the white phenotype. The chromosome-breakage mechanism is, thus, a means of independently and repeatedly producing the same mutation. In this respect, this mutation process is a directed one. McClintock had found earlier that the chromatid

and chromosome breakage-fusion-bridge cycles sometimes produce internal deficiencies within the short arm of chromosome 9, as well as the more frequent terminal deficiencies. Since some mutations are known to be the consequence of homozygous deficiencies, it might be expected that mutations other than pale-yellow or white could arise from these breakage mechanisms. Among a number of mutants which are being investigated, a frequently appearing type resembles in detail the recessive mutant *yg-2*, known to be located within the terminal chromomere of the short arm of chromosome 9. Tests conducted with several of these indicate that they are allelic, if not identical, with each other and with *yg-2*, and that they are likewise allelic with and dominant over the white-seedling mutant. Another internal deficiency within the short arm of chromosome 9, which included the *Bz* locus, has produced the bronze (*bz*) phenotype in tissues that are homozygous for this deficiency. In contrast with the abundant purple or red pigments of the *Bz* plants, the *bz* plants have reduced amounts of purple or red pigments and, in addition, considerable quantities of brown pigment. Although chemical tests have not been conducted yet, it is possible that a mutation to *bz* or a homozygous deficiency for the *Bz* locus results in a disturbance of the interrelated synthesis of anthocyanin (purple or red pigments) and of anthoxanthin (yellow or brown pigments) in the cell.

Kaufmann has continued with studies on the linear organization of the chromosome, and has plotted the positions of more than 1100 X-ray-induced breaks along the X chromosome of *Drosophila melanogaster*. He is also accumulating extensive data concerning the nature and the extent of association between discs at different loci of the salivary-gland chromosomes,

in an effort to locate intercalary heterochromatin and to determine the types of changes which occur within the chromosomes of this species in phylogeny.

The study undertaken by Kaufmann, in cooperation with Miss Gay and A. Hollaender, of the National Institute of Health, of the range of variability in the frequency of mitoses in the epithelium of the cornea has now been completed, and the groundwork laid for appraising effects produced on the mitotic process by short-wave radiations and various pharmacological agents.

Demerec and Fano made a quantitative study of mutations in the B strain of *Escherichia coli* resulting in resistance to seven bacteriophages. Analysis of about 750 mutants showed that they fall into groups; that is to say, that frequently a mutant resistant to a certain phage is also resistant to one or two of the other phages. Mutants quite often differ from one another in the size of colony that they form. Some form large colonies, similar to those of the original strain, and others have small or medium-sized colonies. All together, about twenty different mutant types showing some degree of resistance to seven phages were detected. Since it would be possible to isolate many more phages affecting the B strain, it is evident that the actual number of mutants affecting resistance is considerably larger.

The origin of resistance to penicillin was investigated in *Staphylococcus aureus* by Demerec. It was found that strains resistant to increasingly higher concentrations can be produced by selection. Experimental evidence indicates that resistance is acquired through mutation.

Experimenting with the effect of ultraviolet irradiation of wave length 2537 Å on the B strain of *E. coli*, Mrs. Witkin found that a strain more resistant to this radiation than the original B strain can readily be induced. Her data suggest that,

in this case also, mutation may be responsible for the increased resistance.

Radiation experiments with *Neurospora*, carried on by Sansome, Demerec, and Zimmer, in cooperation with A. Hollaender, have been completed; and the material is now ready for publication. Mrs. Sansome treated spores of *Penicillium notatum* with X rays, and found that morphologically detectable mutants can readily be induced, and that the frequency of mutants increases with the dosage, reaching 45 per cent at 100,000 roentgens.

S. E. Luria, of Indiana University, working at the Department during part of the summer of 1944, continued studies of mutations in bacteriophages. In attempting to induce mutations by ultraviolet irradiation, he discovered that radiation produces a marked delay in the reproduction of phages. This is the first time that a physiological, nonhereditary action of radiation on viruses has been observed.

For a number of years, even while he was located at the California Institute of Technology, a close relation has existed between Th. Dobzhansky and the members of this Department. In 1936, and again in 1938, he spent a summer with us as a guest investigator. When Dobzhansky came to Columbia University, in 1940, our opportunities for contact were greatly increased; and he is now regarded as one of the members of our group. Since his work complements ours, it seems appropriate to include with the reports of this Department the statement Dobzhansky is submitting as a Research Associate of the Institution. His report on last year's work has not yet been published, owing to his sojourn in Brazil during the greater part of 1943; and therefore the report beginning on page 120 covers a two-year period. During this period Dobzhansky completed a study on the genetics, taxonomy, and ecology of flies related to *Drosophila pseu-*

*doobscura* (Carnegie Institution of Washington Publication 554). The main part of this study is concerned with a clarification of the concept of biological race, and with methodology of racial studies. Races are defined as "populations of a species which differ in the incidence of one or more variable genes or chromosome structures." There exist races of quite different orders, beginning with the local populations, which differ from one another only slightly in the frequency of a single or of a few genes, and progressing to sharply distinct groups, which approach the status of separate species. In any case, the intraracial and the interracial variabilities are commensurable, and the genetic constitution of an individual is only partially determined by that of the race from which it came. The work on the dynamics of natural populations of *D. pseudoobscura* led to the discovery of rhythmic alterations in the composition of local populations inhabiting Mount San Jacinto, in California. Certain chromosome structures present in these populations become more frequent and others less so at different seasons of the year. These alterations appear to be due to the fact that the different chromosomes have different environmental optima; that is, some are more favorable under summer conditions, and others in winter or in spring. The species, accordingly, changes from season to season under the influence of natural selection. An apparatus has been constructed by Dobzhansky which permits propagation, in the laboratory, of artificial populations consisting of variants encountered in natural populations. Such artificial populations may, then, be subjected to controlled environmental changes, and attempts may be made to reproduce in the laboratory the elementary evolutionary changes observed outdoors. These attempts have been partially successful; changes analogous to

those that take place in nature during the summer months can be induced under certain conditions in the laboratory populations, whereas under other conditions the laboratory populations remain constant. The seasonal climatic changes in the composition of natural populations of species that inhabit temperate or cold countries may have important repercussions on the evolutionary patterns of these species. A logical question to ask is whether the genetic structure of species inhabiting tropical countries, where the seasonal climatic changes are relatively small, may not be characteristically different from that observed in inhabitants of temperate lands. A program of studies on the genetics of tropical species of *Drosophila* was inaugurated by Dobzhansky in 1943, when collections were made in several parts of Brazil, including the Amazon Valley. Some of the Brazilian species proved to be quite suitable for further more intensive investigations.

The role of longevity in the incidence of spontaneous mouse leukemia has been found by MacDowell, Taylor, and Laanes to be far more complex than had been supposed. Within the data available, longevity is seen to be dependent on numerous variables; both genetic and nongenetic; and the relation of these variables to the incidence of leukemia is diverse. Longevity factors that are specific for any particular cause of death, whether this is leukemia or not, will modify the incidence of leukemia; but nonspecific factors that operate on all causes of death will not, when acting alone, modify incidence. Nonspecific factors, however, when acting together with specific factors, may appear to modify the incidence of leukemia, as when a general, nonspecific resistance reduces a specific susceptibility. Thus a given longevity factor may be associated with the incidence of leukemia in the absence of any direct

physiological relation with the disease. With all recognized influences upon longevity accounted for, there remains, in the experiment designed for this purpose, evidence of genetic control of an underlying tendency, or susceptibility, to leukemia.

The development of endosteal bone following dosage with estrogenic hormone has been shown by Riddle, Rauch, and Smith to occur in the absence of the parathyroid glands. This kind of bone was known to develop in estrogen-treated mammals or birds of both sexes, and to develop cyclically in female birds without treatment; but it had been assumed that the parathyroid glands also were essential to this process. It was reported last year that the parathyroids take no part in the great increase of the "bound" calcium of the blood which follows the injection of estrogen. The exact form in which this "bound" calcium exists in the blood has remained in much doubt, and was made the subject of special study by McDonald and Riddle. The evidence obtained to date makes it seem highly probable that the larger part of the "bound" calcium is attached to the phosphoprotein, serum vitellin. This particular protein was earlier known to increase greatly in the blood at the time of ripening of eggs in egg-laying vertebrates, and also to serve as a binder for some of the excess phosphorus which then appears in the blood. Results of the present study indicate that this binding of phosphorus by serum vitellin at egg-laying extends also to a part of the excess of plasma phosphorus which results from injections of pure estrogen. Thus the evidence obtained indicates that part of the excess of both calcium and phosphorus is bound to the same blood protein, and that this occurs under two conditions which are known to produce an excess of these minerals in the blood.

During the past two years, Fano has had

occasion to re-examine the data contained in Report Number One of the Survey of the Human Resources of the State of Connecticut (see Year Book No. 38, 1938-1939), and to report his findings to a meeting of the Commission, headed by the Honorable F. C. Walcott, which had earlier been appointed in connection with the Survey. These findings indicated that there was particular need for close investigation of at least some group of the moron class within the feeble-minded population of Connecticut. An appropriation was then made by the Institution for resumption of work in this direction. This work will be supervised jointly by Fano and Miss Mabel A. Matthews, director of the Social Service Department of the Mansfield-Southbury Training Schools. A research assistant has been appointed to carry out the work, which was begun on July 1, 1944.

As a result of close collaboration with the Biological Laboratory, a number of geneticists spent the summer with us, making use of the facilities of both the Laboratory and the Department. These included

Max Delbrück, of Vanderbilt University, Th. Dobzhansky, of Columbia University, Myron Gordon, of the New York Zoological Society, S. E. Luria, of Indiana University, Ernst Mayr, of the American Museum of Natural History, James Neel and Curt Stern, of the University of Rochester, and Jack Schultz, of the Lankenau Hospital Research Institute.

In 1940 this Department made available a selected set of *Drosophila* stocks to laymen and to students of biology for simple experimentation in genetics. At the same time, Demerec and Kaufmann prepared a small pamphlet giving essential information for conducting experiments. During the four years this project has been in operation, a considerable number of high schools, and even a few colleges, have availed themselves of the opportunity offered. A total of 1116 cultures have been shipped to 426 high schools and to 43 colleges. The war had no appreciable effect on the demand for this service. The pamphlet, published by the Institution, is now in its third edition.

## THE GENE

M. DEMEREC, U. FANO, AND EVA R. SANSOME

### BACTERIOPHAGE-RESISTANT MUTANTS

Changes to bacteriophage resistance have been known to be fairly specific, inasmuch as each observed change usually involves resistance to only some of the phage strains capable of attacking the original strain of bacteria. The problem of resistance in bacteria therefore offers an unusual opportunity for a quantitative study of the occurrence of specific types of mutants, which outweighs the disadvantage of not being able to check the behavior of the mutants during a sexual process. Such a study was undertaken by Demerec and Fano, assisted by Miss Sturtevant and Mrs. Buchanan. A

detailed description of this work is in press, and only a brief summary will be given here.

In a single strain (B) of *Escherichia coli*, changes to resistance to seven strains of bacteriophage (T<sub>1</sub> to T<sub>7</sub>) were studied. A total of 377 mutants was investigated, and eight different groups were detected. Five of these—B/1, B/1,5, B/3,4, B/3,4,7, and B/6—occur with higher frequency than the other three—B/1,3,4,5, B/6,1,5, and B/7,1,3,4,5. (The numbers following the bar indicate the phages to which the mutant is resistant.) In addition, 364 mutants were derived from lines already resistant

to one or more phages. The cross-resistance pattern in these tests does not significantly differ from the pattern obtained in the previous experiments, where mutants were derived from the sensitive B strain.

The rate of mutation to B/(1,5) was approximately  $10^{-8}$ , to B/(3,4) between  $10^{-8}$  and  $10^{-7}$ , and to B/6 slightly higher. The rate of mutation to resistance to a given phage is similar for the B strain and for strains already resistant to some other phage or phages. These results indicate that mutations to different resistance types are independent of one another and are probably produced by changes comparable to gene mutations.

Extensive tests made with 34 different mutants representative of the material used in this work indicate that the growth rates of mutants do not differ systematically from that of the original B strain, when they are grown together with it.

Evidence indicates that complex mutants resistant to two or more phages may be obtained from B, either by means of a single mutational step or through summation of two or more changes.

It was found that mutants frequently show morphological differences in colony size, which breed true. At least three colony sizes can be distinguished for each of the eight types of mutants; namely, large, small, and tiny colonies. All together, about 20 distinguishable mutant types showing some degree of resistance to our seven phages appeared in our experiments. Since many more phages affecting the B strain could be isolated, it is evident that the actual number of mutants affecting resistance is considerably larger. A correlation between colony size and resistance type was noted. The frequency of small-colony types is higher among B/(3,4,7) than among B/(3,4) mutants.

#### PENICILLIN-RESISTANT STRAINS

A quantitative study on the origin of penicillin-resistant strains in *Staphylococcus aureus* was carried out by Demerec. An effective technique for quantitative determination of resistance was developed, which consisted in growing bacteria in nutrient agar to which sodium salt of penicillin was added to give the desired concentration of penicillin in terms of Oxford units per cubic centimeter.

The strain of *Staphylococcus* used in these experiments is not affected by penicillin in concentrations up to 0.01 units. The killing rate increases rapidly with increase in the concentration, so that at a concentration of 0.1 units practically all bacteria are killed. At 0.0625, about one per million, on the average, survives. Tests made with 38 of these survivors showed that all of them are resistant to the 0.0625 concentration, and that at 0.125 a few of them survive. By selecting, the strains resistant to 0.125 were isolated; and by further repeated selections, strains resistant to 0.25 and to 0.5 were developed. Resistant strains retained their resistance when passed through ten transfers in broth and when kept in agar-slant cultures for about three months. These experiments indicated that strains resistant to penicillin can be developed and that resistance can be built up by selection.

The question of how resistance is produced was next investigated. Is the change in bacteria induced by the action of the penicillin, or does it originate independently of the penicillin, by a process similar to mutation, and the penicillin act only as a selective agent in isolating mutants? Simple experimentation furnished a fairly conclusive answer to this question. The technique used in all experiments was such that penicillin came into contact with the bacteria only when tests for resistance were

made. All bacterial cultures were grown in a penicillin-free medium. In these experiments, cultures were started from a small inoculum containing less than 300 bacteria per cubic centimeter, and grown to about 300 million per cc. A number of samples, of about 150 million bacteria each, were taken from *one* culture; and each sample was plated on a nutrient agar containing 0.0625 units per cc. of penicillin, in order to determine the number of resistant bacteria in each sample. Similar samples were taken from other independent cultures, one from each culture, and the number of resistant bacteria determined. If the resistance had been induced through the contact of bacteria with penicillin, it would be expected that the number of resistant bacteria per plate would be similar in all samples, and that variation would follow a Poisson distribution. If, on the other hand, the resistant bacteria had originated by mutation, and the mutations had occurred at random, then it would be expected that in some cultures they might occur early and produce a large proportion of mutants, and that in others they might occur late and give rise to a small number of mutants. In this case, the variability between samples taken from independent cultures would be expected to be greater than the variability between samples taken from one culture. This was found to be true to a significant degree, indicating that resistance to penicillin had originated through mutation.

If the change to resistance is a genetic change, then the effect of selection on increase of resistance can readily be explained by the assumption that many "genes" affect resistance, and that their effect is additive.

It may be of interest to note that the progress in the building up of resistance is more rapid with each selection step. For example, almost all bacteria of the original strain are killed at a concentration of 0.1

unit, those of the first-step resistant strain at about 0.14 unit, of the second-step resistant strain at about 0.28 unit, of the third-step resistant strain at about 0.6 unit, and of the fourth-step resistant strain at about 2 units. This observation may be of considerable importance in the planning of therapeutic treatment with penicillin, since it suggests that in order to avoid a building up of resistant strains, it is imperative that treatment be begun with a concentration that is high enough to eliminate all bacteria of the strain against which treatment is used.

#### ULTRAVIOLET RESISTANCE

In an experiment carried on by Mrs. Evelyn Maisel Witkin, strain B of *Escherichia coli* was irradiated with ultraviolet light at a series of dosages. A germicidal lamp manufactured by General Electric Company, which emits ultraviolet radiation of wave length 2537 Å, was used in these experiments. Colonies developing from survivors of the higher-dosage treatments, where killing is of the order of 99.98 per cent, were isolated and cultured in broth. These cultures were found to be relatively resistant to the bactericidal action of ultraviolet rays. The resistance of strains so established was maintained unchanged through more than thirty broth subcultures, and for a period of two months on agar. It may therefore be considered a stable heritable character.

Survival curves for the normal and resistant strains were established. Samples were taken from 24-hour aerated broth cultures, diluted in broth, and spread on the surface of agar plates so that half of each plate was spread with the normal sample and half with the resistant sample. The plates were irradiated immediately after spreading, at a constant voltage and distance from the source. Dosage was determined by the time of exposure. Non-

irradiated control samples were taken from the same cultures and plated in the same way.

The difference in killing rate between the two strains is greatest in the first two minutes of irradiation. In this range the rate of killing is considerably higher for the normal strain. After two minutes the killing rate of the resistant strain increases, and the two curves become approximately parallel. The change in slope in the normal curve between one and two minutes indicates a possible screening effect, which has not yet been controlled. There is some evidence, however, that the normal samples contain a proportion of resistant cells sufficient to account for the change in slope at these doses. This possibility will be further investigated.

Despite the quantitative nature of the resistant character, the population of a resistant culture seems to be genetically homogeneous. A series of ten single-cell cultures from the resistant strain were tested through the dosage series, and all gave survival curves identical with that of the mass culture.

The problem of the origin of the change to resistance has not yet been systematically investigated. There are preliminary indications that the change is a mutation arising independently of ultraviolet treatment. For example, it has been shown that the chance of recovering resistant survivors from a single-cell normal culture increases with the number of divisions the culture is allowed to undergo.

#### RADIATION EXPERIMENTS WITH *NEUROSPORA*

The investigations on the effect of X radiation and ultraviolet radiation in inducing mutations in *Neurospora* were continued by Mrs. Sansome, Dr. Demerec, and Miss Zimmer, in collaboration with Dr. Hollaender, of the National Institute of Health, Bethesda, Maryland. Previous

experiment had indicated that the ultraviolet mutation curve for microconidia of *Neurospora crassa* resembles that of the spores of *Trichophyton mentographyes* and certain other fungi. The curve reaches a peak at a certain energy level and drops with a further increase of energy. Such behavior seems to indicate heterogeneity either in the amount of treatment received by each spore or in the response of the spores to irradiation. The conditions of irradiation appear to preclude the possibility of heterogeneity of treatment. In considering the possibility that the spores are heterogeneous in their response to ultraviolet treatment, the simplest hypothesis is that a few of the spores are binucleate and that these survive the high dosages and give normal phenotypes, since any mutation in one nucleus is covered by its normal allele in the other nucleus. The X-ray results, however, which show a continuous apparently linear increase in mutation rate with increase in dosage, are not in accordance with this hypothesis. There remains the possibility that the spores differ in their capacity to absorb the ultraviolet or to give a mutational response to it. In order to test whether the age of the spores had any effect on their response to ultraviolet treatment, the mutation rates of suspensions of spores from cultures wetted down one day prior to treatment were compared with those of sister cultures wetted down two days previous to treatment. The results were inconclusive. In two experiments the younger spores gave the highest mutation rates, and in two others the older spores gave the highest mutation rates.

It was thought that most of the phenotypic normals from spores subjected to high dosages might result from spores which were capable of giving chromatid and not chromosome effects. This would lead to the production of heterokaryons; that is, cultures containing more than one kind of nucleus. Some of these would be

balanced heterokaryons, consisting of two types of nucleus each with a different mutational change. Since each nucleus carries the normal allele of the mutation in the other nucleus, the heterokaryon might be expected to appear normal. If the phenotypic normals from high dosages result from spores which give only chromatid effects, a high proportion of normals from heavily treated spores should be balanced heterokaryons. Accordingly, the genetic constitution of 49 such normals was ascertained by plating out and isolating microconidia obtained from them. Only one was a balanced heterokaryon. However, chromatid effects are probably quite frequent in ultraviolet-irradiated spores of *Neurospora*, since a number of cultures which first appeared mutant and later reverted proved to be heterokaryons.

Genetic analysis of 60 ultraviolet-induced mutants showed that more than one locus was involved in 24 of these. This high rate of formation of multiple mutants is evidence for the occurrence of heterogeneity either in the treatment or among the spores themselves. Moreover, the variability of different spore samples is in accordance with the presence of heterogeneity. The cause of the heterogeneity, however, is not determined.

So far as the X-radiation experiments are concerned, it was reported in Year Book No. 42 that the mutation rates for dosages given at 5400 roentgens per minute were higher than those for the same dosages given at an intensity of 240 r per minute. An experiment to test this apparent intensity effect showed that a continuous dose of 31,500 r at an intensity of 5400 r per minute was more effective in producing mutations than either a fractionated dose with a gap of three hours between the treatments or a continuous dose of 31,500 r delivered at an intensity of 270 r per minute. The difference between the two continuous doses at different intensities

is 2.5 times the standard error of the two, and is therefore significant.

Many of the cultures resulting from X-ray-treated spores are partially sterile when crossed with a standard line. This sterility, which is assumed to be generally due to the presence of chromosomal aberration, is more frequent among visible mutants than among the phenotypic normals. An analysis of sterility and visible mutants at different dosages and intensities was made, in an effort to determine the nature of the changes appearing as visible mutants. When the same dosage is given at different intensities, it is found that the percentages of visible mutants and of steriles are higher for the high intensity. This is believed to indicate that some of the visible mutants result from aberrations, since it is considered that the number of initial effects produced by the same dosage is probably the same whatever the intensity. If all visible mutants were the result of aberration, the proportion of such mutants among the steriles should be the same—apart from the effect of multiple aberrations—whatever the dosage. It was found, however, that with increase of dosage the proportion of visible mutants among the steriles is increased; whereas when the numbers of mutants and of steriles are increased by increasing the intensity (the dosage being constant), the proportion of steriles which are also visibly mutant remains constant. This indicates that there is a class of mutants distinct from those resulting from aberrations. It is not possible on the basis of the present data to distinguish between mutants that are induced directly by the treatment, but may be associated with aberrations, and mutants that are entirely independent of aberrations.

#### X-RAY EXPERIMENTS WITH *PENICILLIUM*

In a series of experiments made by Mrs. Sansome with *Penicillium notatum*, the

proportions of visible mutants were recorded at different X-ray dosages, and the effect of various factors on their frequency was determined. For these experiments the strain N.R.R.L. 832 was used, and spores were taken from cultures 5-7 days old, not more than three weeks removed from the single-spore stage. The irradiation was given by Mr. L. D. Marinelli at the Memorial Hospital in New York, at an intensity of 2420 roentgens per minute.

It was found, as in the case of *Neurospora*, that the earlier-germinating spores gave the same percentage of mutants as the later-germinating spores. The results per dosage of 50,000 and 100,000 roentgens are given in the table:

TREATMENT	ISOLATED FIRST DAY		ISOLATED SECOND DAY	
	Total	% mutants	Total	% mutants
50,000 r . . .	323	25.1	410	21.5
100,000 r . . .	142	43.7	200	45.0

The percentage of mutants obtained from spores irradiated on the agar slant is approximately the same as that from spores irradiated in physiological saline. The percentage of visible mutants increases in a linear fashion from 9.4 per cent for 25,000 r to 30 per cent for 100,000 r, as shown in the following table:

The survival value was estimated for spores irradiated in physiological saline. The method used was to plate out control and treated samples from one original suspension and to relate the number of colonies from the different treated samples to the number from the control. It was found that over 40 per cent of the spores survived a treatment of 25,000 r. The survival rate at the highest dosage recorded, 100,000 r, was only 0.06 per cent. An effort was made to compare the survival rates of spores irradiated in suspension and on the agar slant. In this case the number of spores in the original spore suspension, as estimated by a count made in a blood-counting chamber, was taken into account. It appears that at high dosages the survival value is lower for spores irradiated in suspension than for spores irradiated dry. About 1.69 per cent of spores irradiated on the agar slant survived 100,000 roentgens, whereas at the same dosage only 0.06 per cent survived when irradiated in suspension in saline.

The effect of storing spores in the refrigerator after irradiation was tested. It was found in the batch tested that the spores stored for 20 days gave a slightly higher mutation rate than spores plated immediately after irradiation, but that the difference was not significant.

VISIBLE MUTANTS AND SURVIVAL RATES

Treatment	Total recorded	No. mutants	% mutants	Survival ratio (%)
Controls . . . . .	599	1	9.4	100.0
25,000 r wet . . . . .	403	38	16.4	40.8
50,000 r wet . . . . .	372	61	16.4	9.5
50,000 r dry . . . . .	286	45	15.7	18.2
50,000 r wet + dry . . . . .	658	106	16.1	..
75,000 r dry . . . . .	246	45	18.3	7.7
100,000 r wet . . . . .	177	57	32.2	0.06
100,000 r dry . . . . .	220	62	28.2	1.69
100,000 r wet + dry . . . . .	397	119	30.0	..
50,000 r dry, plated after 20 days .	158	37	23.4	2.47

### HETEROKARYONS IN NEUROSPORA

When two different mutants with a reduced growth habit are grown in the same culture, they will usually form a heterokaryon with a normal growth habit. It can be proved that mixing of nuclei within the same mycelium occurs. Experiments made by Mrs. Sansome showed that these heterokaryons can be split up into their components by making microconidial isolations from them. This affords direct evidence of the uninucleate condition of the microconidia. Attempts to produce heterokaryons by putting together mutants of opposite mating types were unsuccessful. Even hyphal tip cultures taken from young perithecia, when mating is presumed to have occurred, were homokaryotic. Thus it seems that vegetative heterokaryons, involving nuclei of opposite mating types, cannot be produced in *Neurospora crassa* by inoculating the two types together. If this is so, it has considerable importance in any consideration of the life history of the organism.

### MUTATIONS IN BACTERIOPHAGE

During part of the summer of 1944, Dr. S. E. Luria, of Indiana University, continued at this Department his work on the recently discovered mutations of bacteriophage. From several of the phages used by Demerec in his work on phage-resistant bacteria, mutant phages were isolated. The mutant phages differ from the original phages by their ability to attack one or more bacterial strains resistant to the original phage. The proportion of mutants in suspensions of normal phage varies greatly in different cases, indicating variations in the mutation rate. Preliminary evidence was collected which seems to suggest that, in some

cases at least, the abnormal colonies of resistant bacteria which often appear after lysis of sensitive bacteria by a phage owe their morphology to the secondary action of mutant phages active on the resistant bacteria.

In the course of preliminary experiments on the induction of mutations in bacteriophage by ultraviolet irradiation, an interesting new effect was discovered. After irradiation, when a fraction of the phage particles has been inactivated, the surviving particles show a marked delay in their action on sensitive bacterial hosts, as studied by one-step growth experiments. The adsorption of phage by the host and the yield of phage per bacterium are not affected, but phage liberation takes place after a delay and at a slower rate, indicating a slowing down of one or more of the steps leading to liberation of phage (penetration, growth, lysis). The delay effect increases with increasing amounts of radiation. There is no demonstrable recovery upon dilution and storage of the irradiated phage. The effect is, however, strictly nonhereditary; the offspring of the irradiated particles grow normally. The experiments were done under conditions which exclude the possibility that the delay effect is due to interference by the inactive phage particles present in the irradiated suspensions. The effect was observed with three unrelated phage strains active upon *Escherichia coli* B. The lamp used gave about 80 per cent radiation of 2537 Å.

The effect described above represents the first instance of a physiological, non-hereditary action of radiation on viruses, as distinguished from lethal and possible genetic effects. The delaying action on phage liberation may fall in a class with the well known delaying actions on division of microorganisms and higher cells.

## CYTOLOGY

BERWIND P. KAUFMANN

## ORGANIZATION OF THE CHROMOSOME

Although the chromosomes of the salivary glands of *Drosophila melanogaster* have been used extensively in cytogenetic studies during the past ten years, many details of their linear organization remain unknown. As viewed microscopically, each chromosome reveals a constant and specific pattern of banding; these details have been incorporated in maps made by C. B. Bridges, P. N. Bridges, and others. Each detectable disc of the chromosome has been designated by a letter and a numeral; for example, in *D. melanogaster* the entire chromosome complex has been divided arbitrarily into 102 numbered divisions, each of which is in turn marked off into six lettered subdivisions (A to F), within which the specific bands are again numbered. In this species the X chromosome comprises divisions 1 to 20, the second chromosome divisions 21 to 60, the third chromosome 81 to 100, and the fourth chromosome 101 and 102. These details, familiar to cytogeneticists, are recounted here to facilitate understanding of the data presented in the following paragraphs by those less well acquainted with the system used in identifying various loci along the chromosomes.

Salivary-gland chromosomes are many times larger than actively dividing chromosomes of the same individual, but they are not mere replicas on a grander scale. Genetic and cytological studies have shown that large fractions of the actively dividing chromosome may be represented by a very small number of discs in the salivary-gland counterpart. The Y chromosome of *D. melanogaster*, a clearly discernible J-shaped body of the chromosome complex of the male fly, is barely detectable in salivary-

gland preparations, and the proximal third of the X chromosome of the mitotic cell of flies of this species is represented by 19 of the 1012 discs portrayed by C. B. Bridges in his salivary-gland chromosome map.

The phenomenon of differential expression of such regions in the salivary-gland chromosome has been attributed to their heterochromatic nature. The Y chromosome and the proximal third of the X chromosome of *D. melanogaster*, for example, are clearly outlined in the early stages of the mitotic process as dark-staining blocks, whereas the major part of the chromosome complement is relatively inconspicuous. This precocious condensation, or heteropycnosis, is one diagnostic feature by which that part of the heterochromatin that is present in large blocks (the so-called staining blocks) may be differentiated cytologically from the remainder of the chromosome, which is generally designated as euchromatic. There is some evidence, however, that heterochromatic regions of lesser extent are also distributed along the euchromatic part of the limb. The chromomeres, which first become conspicuous along the chromosomes of *Drosophila* in the early prophase stages of mitosis, and which have generally been regarded as aggregates of smaller chromomeres, may represent such intercalary heterochromatin.

The effort to locate such intercalary heterochromatin is not merely a problem of reinterpretation and augmentation of existing maps. Development of the concept that the activity of a gene is not independent of its position in the chromosome emphasizes the necessity for a more complete knowledge of the details of chromosome organization. It is to be hoped also

that accumulation of such information will cast additional light on the changes that occur within the chromosomes in phylogeny, changes by which genic materials are added to the chromosomes as duplicated sections within which mutational changes may subsequently occur to cause a divergence from the parental pattern.

For these reasons additional data have been accumulated on the distribution of heterochromatic regions within the chromosomes of *D. melanogaster*, the species on which the most extensive genetic studies have been made. There are several criteria by which these regions may be identified cytologically. The chromomeres comprising the discs found in the proximal heterochromatic regions, the so-called heterochromomeres, are vesicular and somewhat larger than those of euchromatic regions. Chromomeres of this type are rarely observed in more distal parts of the chromosomes, so that if intercalary heterochromatin is present it is not detectable by this criterion. The proximal heterochromatin of such species as *D. melanogaster* also exhibits the property of nonspecific pairing, all the chromosomes being drawn together in the regions close to the centromeres to form a chromocentral aggregate. When intercalary or terminal regions of the chromosome participate in this type of pairing, it may be assumed that they possess some properties similar to those of the proximal heterochromatin. The frequency with which breaks occur, following exposure of chromosomes to irradiation by X rays, may also furnish an index of the position of heterochromatic regions. Another criterion by which intercalary heterochromatin may possibly be identified has been outlined by Schultz (Year Book No. 40); it involves the location by cytogenetic techniques of those loci which affect the expression of mosaicism or variation in somatic cells.

The first study of the distribution of X-ray-induced breaks along the X chromosome of *D. melanogaster* was reported in Year Book No. 38. At that time 475 breaks had been determined within the limits of the lettered subdivisions of divisions 1 to 19 of Bridges' 1938 map. In the course of analysis of salivary-gland chromosomes during more recent years, this number has been increased to 845. Another group of 272 breaks has been localized in the proximal heterochromatic region (division 20). The percentage of the total which they represent (24.4) is smaller than the 33.3 to be expected on the assumption that breaks are distributed at random according to the length occupied by the region in the mitotic chromosome (Kaufmann and Demerec, 1937). In the cytological analysis of salivary-gland chromosomes, however, many rearrangements which are restricted to the proximal heterochromatic regions are not detected. When calculations are adjusted so as to incorporate these cytologically undetected changes, the percentage of breaks in the proximal heterochromatic region of the X chromosome rises to about 29.6. Although these data in themselves do not enable a decision to be made between the two alternatives—namely, that break frequency in this proximal heterochromatic region is proportional to mitotic chromosome length, or that it is dependent on the high fragility of a few loci that alone are susceptible to breakage—the experimental values obtained are close to those expected on the first assumption. This point will be considered subsequently.

The distribution of the 845 breaks along the distal two-thirds of the X chromosome (generally designated as euchromatic) has been compared, using the chi square method, with the distribution to be expected on the assumption that breakage is at random per length of salivary-gland

chromosome. Considering first the breaks within each of the 19 divisions, the probability ( $P$ ) is considerably less than 0.01 that the observed distribution merely represents a departure from randomness because of the error of sampling. Complete data cannot be furnished here, but it is interesting to note, in view of Bauer's suggestion that break frequency is highest in distal regions, that divisions 1, 3, 4, 11, 12, and 19 show a considerable number of breaks in excess of expectancy, whereas divisions 5, 6, 10, 13, 14, 15, 17, and 18 show many fewer than expected. The remaining 5 divisions show only slight departures, plus or minus, from values anticipated on the assumption that breaks are distributed at random. The three divisions with the highest break frequency are 1 (terminal), 11 (medial), and 19 (proximal).

The reasons for these wide departures from expectancy become clearer when the break frequency is calculated for the individual lettered subdivisions. Of these, 11A, 12E, and 19E show the largest numbers of breaks in proportion to salivary-gland chromosome length represented. Other subdivisions showing an exceptionally high break frequency are 1F, 3C, 4DE, 5D, 7B, 7C, 16F, and 19F. Since in the property of high break frequency these regions resemble the proximal heterochromatic regions, it seems probable that they also contain heterochromatic materials.

The regions of highest break frequency—namely 11A, 12E, and 19E—are characterized cytologically by repetition of the sequence of banding in the pattern of a "reversed repeat" (the *abccba* type). Occasionally the linear continuity of the salivary-gland chromosome appears to be disrupted in these regions, either by the divergence in the form of a V of the two adjoining homologous discs of the repeat series, or by their wider separation. Such a rupture or "break open" may at times be

brought about by pressure on the chromosomes in flattening the cells for observation, but is more generally to be attributed to pairing in an early stage of development among the bands of the repeat series. Evidence for this interpretation is furnished by pairing within haploid strands, and by experimentally induced "reversed repeats." If a ruptured chromosome may serve as a clue to previous intrachromosomal pairing, the frequency with which the rupture appears should indicate the degree of homology existing between the discs of the two repeated series. Studies of such frequencies are now being made. In the X chromosome, more than 200 ruptures have been recorded in subdivisions 3C, 11A, and 12E; of these 53 per cent were in 11A, 36 per cent in 12E, and only 11 per cent in 3C. It will be recalled that the first two of these subdivisions showed a much higher break frequency when exposed to X rays than did 3C. Both these methods may furnish, therefore, an index to quantitative, or possibly qualitative, differences in intercalary heterochromatin. Other subdivisions in which ruptures occur, but for which quantitative data are not now available, are 19E, 42B, 70C, 75C, and 89E.

Measurements are also being made, in cooperation with Miss Marcia Kelman, of the degree of nonspecific pairing throughout the chromosome complex of *D. melanogaster*. As an example of the type of information obtained, the bands of the 11A repeat series have been observed to pair with bands in 1E, 7C, 9B, 12E, 16A, 64C, 73B, 87B, and 98C. Many other similar series have been recorded. Several hundred cases of association between individual bands, both within and between chromosome limbs, have likewise been detected. The cytological observations must be augmented considerably, however, before the intercalary heterochromatic and

duplicated euchromatic regions can be mapped with precision, and the findings integrated with known genetic data.

It was indicated previously that the distribution of induced breaks along the chromosomes may be interpreted as supporting the contention that break frequency is proportional to mitotic chromosome length. On the contrary, Muller, Gershenson, and their colleagues (Muller and Gershenson, 1935; Muller, Raffel, Gershenson, and Prokofyeva-Belgovskaya, 1937) have advanced the theory that breaks in the proximal heterochromatic region of the X chromosome are not distributed at random, but occur at only a very few points. The evidence on which this theory rests is of the following type: A deficiency for bobbed lacked a piece nearly equal to the length of the proximal heterochromatic region. Subsequently it was reported that the locus of bobbed could be separated from this large block, which was designated as Block A (Muller *et al.*, 1937), but that it still included "the major portion of the inert region of the mitotic chromosome." In the salivary-gland chromosome, Block A is presumably represented by a single faint disc.

To what extent, then, is Block A an indivisible unit? An approach to this problem has been made by cytological analysis of a series of inversions having one break in the proximal heterochromatic region, the other near the left end of the X chromosome. Such a study is best made on the neuroblast cells of the larval ganglion, at the stage of prophase when the heterochromatic materials are most clearly defined and the nucleolus stands as a landmark dividing the proximal third of the X chromosome into two parts of about equal length. Any redistribution of heterochromatic materials as a result of inversion can thus be detected by the proportion of

deeply staining material lying at the two ends of the inverted section.

Inversion roughest<sup>3</sup> extends from band 3C3 to about subdivision 20B. The rightmost break lies sufficiently far to the right of the locus of the gene bobbed to include several discs of heterochromatic material from 20A and 20B. That these discs represent no minute fraction of the total heterochromatic zone is indicated by the fact that this displaced material increases the length of the genetic map in the distal part of the X by about 10 units (Grüneberg, 1937). The rightmost break of the *rst*<sup>3</sup> inversion, however, lies to the left of the nucleolus, and is therefore within the distal half of the proximal zone of heterochromatin. In an earlier study several reversions from roughest to wild type were obtained, and these were associated with chromosomal alterations, each of which involved at least one break in the proximal heterochromatic region of the X. Several of these were to the right of the nucleolus-organizing region, as revealed by the removal of the nucleolus from the X chromosome. In these cases, nevertheless, a considerable bulk of detectable heterochromatic material remained adjacent to the centromere. Thus, breaks associated with the *rst*<sup>3</sup> inversion and its reversion separate the proximal heterochromatic region of the X into at least three parts of measurable size; and this information is difficult to reconcile with the concept of a block which lies to the right of bobbed and which includes the major portion of the "inert" region.

Because of these findings, it seemed desirable to inquire whether the nucleolus might not be useful in revealing the positions of breaks used by Muller and his coworkers in determining the extent of Block A. Three inversions are of particular interest—namely, white-mottled 4, scute L8, and scute 8—because in the first two

the points of breakage and reattachment are reported to have occurred between the locus of bobbed and Block A, whereas in scute 8 the break was to the right of Block A. By studying both ganglion and salivary-gland nuclei of males and homozygous females, the nucleolus was found to have been included within the limits of the *sc*<sup>8</sup> and *sc*<sup>L8</sup> inversions, but not in the *w*<sup>m4</sup> rearrangement. This information also indicates that Block A is not an indivisible unit, for in *sc*<sup>L8</sup> the presumptive break between bobbed and Block A lies to the right of the nucleolus-organizing region, whereas in *w*<sup>m4</sup> it is to the left of that region. It is thus clear that if Block A is represented by a single band in the salivary-gland chromosome, it must lie to the right of the nucleolus, perhaps in 20C, and under such conditions Block A could hardly constitute the major portion of the proximal heterochromatic region.

In the light of this analysis, it would seem that the evidence concerning staining blocks does not negate the contention that breaks in the proximal heterochromatic region are distributed at random according to the mitotic chromosome length involved. The break frequencies which we have found approach percentages expected on the basis of prophase chromosome length, not only in the X chromosome, but also in the autosomes. Satisfactory cytological as well as genetical proof is required before these facts may be attributed to mere coincidence.

#### MITOSIS IN THE EPITHELIUM OF THE CORNEA

As indicated in Year Book No. 42, a study was undertaken, in cooperation with Miss Helen Gay and with Dr. Alexander Hollaender, of the Division of Industrial Hygiene of the National Institute of Health, of the effects of ultraviolet radiation on the dividing cells of the epithelium

of the cornea of the mammalian eye. The preliminary survey of a series of untreated or control corneas indicated that considerable variability in the frequency of mitoses might exist within a single cornea or between the two corneas of one animal. Inasmuch as determination of the range of this variability was essential to any further experiments involving comparisons of treated and control areas, and since we had developed a method for rapidly counting the dividing cells, a more extensive study was made this year of the range of this variability in corneas of albino rats and of New Zealand White rabbits, both of which were obtainable in inbred stocks that could be maintained for further experimental work.

These studies showed that mitoses were about 19 to 20 times as frequent in the epithelium of the cornea of the rat as in that of the rabbit. In the rat we have counted as many as 650 dividing cells per square millimeter. In general, mitoses are least abundant peripherally, and increase along a gradient toward the center. In such a large cornea as that of the rabbit, the gradient is steep, but it is slight to insignificant in the smaller cornea of the rat. Consequently, variability from region to region is much less in the rat than in the rabbit.

Inasmuch as the counting of mitoses in the entire cornea is both laborious and time-consuming, various sampling procedures were tested. It was found that counts of mitoses in a meridional strip across the whole cornea furnish a more reliable index of the frequency in the entire cornea than counts made in an isolated region. Counts made on two or more strips within the same cornea fall within the range of the sampling error, as determined by the chi square method. Wedge-shaped sectors, extending from the

periphery to the center, do not show such uniformity.

The difference between the two corneas of the same animal in frequency of mitoses may also be considerable. Ratios of frequency in the two eyes of about 1.1 to 0.9 are not uncommon. Such differences must be considered in experimental work in which the treated cornea is compared with the other cornea of the same animal serving as a control. When experiments proceed on the assumption that the number of mitoses is equal in the two eyes of an animal (for example, Gurwitsch and Aniken, 1928, in a study of the effects of mitogenetic rays), the conclusions must be open to considerable suspicion.

Counts were also made on the proportions of cells in the various stages of mitosis. In round numbers, about 40 per cent of the period of active cell division is represented by the prophases, about 20

per cent by the metaphases, about 10 per cent by the anaphases, and about 30 per cent by the telophases. These proportions, although differing in some particulars, are of about the same order of magnitude as those given by several workers with tissue cultures. Since the proportions were found to be relatively constant from preparation to preparation, counts made on the more conspicuous stages, such as metaphase and anaphase, furnish under certain conditions a reliable index of the over-all frequency.

The establishment of the range of variability in the frequency of mitoses in the corneas of the eyes of these mammals, and the development of methods for rapidly preparing the material for cytological analysis, will facilitate studies, such as we have undertaken, of the disturbances produced by short-wave radiations and various pharmacological agents on the mitoses of the corneal epithelium.

## GENETIC STRUCTURE OF NATURAL POPULATIONS

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As outlined in previous reports (see Year Books Nos. 37 to 41, especially No. 41), the general purpose of this research program is investigation of the hereditary variability present in natural populations, and its role in the process of evolution. On account of their many technical advantages, the small flies belonging to the genus *Drosophila* are chosen as the test material, but it is hoped that the results obtained may be of a more general applicability. This hope is based on the well established generalization that the fundamental laws and mechanisms of heredity are (notwithstanding some striking exceptions) remarkably uniform throughout the living world.

Several lines of attack are being pursued simultaneously, converging on a clarification of the breeding structure of the

natural populations of certain species of *Drosophila*, and of evolutionary changes taking place therein.

### DISPERSION RATES IN DROSOPHILA PSEUDOBOSCURA

Experiments reported previously (see Year Books Nos. 39 to 41) have shown that *Drosophila pseudoobscura* which inhabit the forested part of Mount San Jacinto (California) do not represent a single undivided population. Instead, there is a mosaic of populations, each of which occupies only a small fraction of the territory. Although these small populations merge into one another, they are able, within limits, to accumulate genetic differences, and consequently to pursue different evolutionary courses. Such a situation can

obtain only if the flies, despite their possessing apparently efficient means of locomotion, are fairly sedentary in their habits, so that the inhabitants of a given small territory do not mix at random with inhabitants of neighboring territories. Attachment to a small territory despite possession of efficient organs of locomotion is, of course, known in many animals, some migratory birds being outstanding examples. The above conclusions regarding the breeding structure of the *Drosophila pseudoobscura* populations and the sedentary habits of this fly have been reached, however, not on the basis of direct observations, but as a result of what may seem to be very indirect evidence; that is, studies on the concentrations, frequencies of allelism, and mutation rates of recessive lethals in the third chromosome. (The mathematical analysis of these data was made by Professor Sewall Wright, of Chicago.) It was obvious throughout this work that independent evidence that would permit a check on the validity of these conclusions would be very desirable. Experiments were started, consequently, in the summer of 1941 on Mount San Jacinto to obtain data on the dispersal rates and on population densities of the flies (see Year Book No. 40). The technical difficulties encountered in these experiments were unexpectedly great, but in the summer of 1942 a fairly satisfactory technique was finally evolved. The data have been analyzed by Professor Wright.

In brief, the experiments and the conclusions are as follows. A known number of flies marked with an easily recognizable mutant character (the orange eye color) are released at a given point. On the following and successive days, two lines of traps containing a substance attractive to the flies are set, crossing each other at right angles at the point of release. The numbers of marked and unmarked (wild) flies

that visit the traps at various distances from the point of release are recorded daily, and the flies are liberated where captured. The distribution of the marked and wild flies on successive days on the experimental field permits a number of inferences to be made. First of all, the type of dispersal characteristic of our species must be determined. In a uniform two-dimensional medium the flies may move at random, somewhat like molecules engaged in the Brownian movement; if so, the variance of their distribution around the point of release will increase proportionally to time. On the other hand, the released flies may establish "home territories," or may escape from territories with higher to those with lower population densities; in these events the variance would grow rapidly for some days following the release of the marked flies, and progressively slower with time. The data obtained indicate that the flies move approximately at random. The average distance traveled by the flies is greatly influenced by temperature. If the temperature at the time of the maximum abundance of the flies in the evening is 55° F. or less, the flies move little or not at all. At about 70° F. the average distance traveled by a fly per day is around 100 meters, and at 80° F. it is probably of the order of 200 meters per day. It must be kept in mind that, since the movements are random, if the flies travel 100 meters per day, in  $n$  days they will have traveled not  $100n$ , but only  $100\sqrt{n}$  meters on the average.

The number of marked flies caught on the experimental fields gradually declines with the passage of time after the release. This decline is due in part to the mortality of the flies, and in part to their becoming scattered into territories where no traps are set. With the aid of an appropriate mathematical analysis it is, however, possible to estimate that the number of the released flies declines about 8 or 9 per cent

per day under the conditions of the experiments. Therefore, the flies in their natural habitats do not live so long as in laboratory cultures at the same temperature. Comparisons of the numbers of released and of wild flies trapped on the experimental fields permit certain deductions regarding their absolute population densities. The figures arrived at for different experimental plots in midsummer on Mount San Jacinto range from 400 to 800 wild flies per 10,000 square meters of the area. It must be emphasized that such population densities are doubtless closer to the maximum than to the minimum reached by our species in nature. Indeed, the experiments were made in a region and at a time of the year when the flies are known to be very abundant.

The genetic work on the frequencies of third-chromosome lethals has indicated that the effective population size ( $N$  of Wright's formulas) of *Drosophila pseudoobscura* on Mount San Jacinto is approximately 50 per 10,000 square meters; that is, only from one-eighth to one-sixteenth of the population densities observed in midsummer. Strange as it may seem, this may be regarded as a good agreement. Indeed, as has been shown theoretically by Wright, the genetically effective population size is likely to be very much lower than the maximum population density reached at favorable seasons. The effective population embraces only those individuals that leave surviving adult offspring, and its numerical value is determined much more by the minimum than by the maximum population densities reached by the species in its periodic expansions and contractions. Further experiments which should throw additional light on the population structure in *Drosophila pseudoobscura* are planned, but have had to be postponed owing to wartime conditions.

#### SEASONAL CHANGES IN THE GENETIC COMPOSITION OF POPULATIONS

It has been found (see Year Book No. 40) that the composition of at least some populations of *Drosophila pseudoobscura* is in a constant flux, significant changes being observable from month to month. This is a rather unexpected finding, because changes in the genetic composition of natural populations are evolutionary changes by definition, whereas it is conceded by most biologists that evolutionary changes in nature are mostly too slow to be observed directly in a human lifetime. However that may be, at certain localities on Mount San Jacinto the frequency of the flies having the so-called "Standard" gene arrangement in their third chromosomes reaches a maximum during the period from midsummer to early spring (March), and a minimum in early summer (June); the frequency of the "Chiricahua" gene arrangement undergoes a cycle which is the reverse of that of the "Standard"; and the "Arrowhead" gene arrangement changes its frequency relatively little. For an interpretation of these changes, the fact that they are connected with the annual climatic cycle seems to be illuminating. It suggests the hypothesis that, in the populations where the changes are observed, the different chromosome types are subject to natural selection. The "Standard" chromosomes, or at least a majority of them, contain genes which are favorable to the flies in summer environments and relatively unfavorable in spring; the gene contents of the "Chiricahua" chromosomes are advantageous in spring but disadvantageous in summer; the "Arrowhead" chromosomes have no seasonal advantages or disadvantages. Natural selection causes a reconstruction of the species in accordance with the seasonal changes in the environment.

The changes take place with great speed; for example, in one of the localities the frequency of the "Chiricahua" chromosomes in the population is about doubled in spring, and then reduced to approximately one-half in summer, within a space of about four months. The average number of generations that the flies can produce during this time can hardly be greater than five or six. Now, if the selective advantages and disadvantages of the different types of chromosomes are as great in nature as these observations indicate, we must be able to reproduce in laboratory experiments at least some of the changes wrought by natural selection outdoors. To test this, artificial populations of flies whose ancestors were captured on Mount San Jacinto have been created and studied.

A modification of the apparatus for making artificial populations of *Drosophila* devised some years ago by l'Heritier and Teissier is being used. Our version is a  $43 \times 30 \times 13.5$  cm. box with a wooden bottom, a glass top, and a wire screen in one of the sides for ventilation. The bottom has 15 openings closed by corks, each of which carries a Stender jar with regular *Drosophila* culture medium. At the beginning of the experiment, a known mixture of the flies with different gene arrangements in their chromosomes is introduced into the box. At regular intervals one of the corks is withdrawn, a jar with fresh culture medium substituted for the one with the worked-out medium, and the cork returned to its old place. With some practice this operation can be accomplished with few or no flies escaping from the box. The fly population in the box grows to a size compatible with the amount of food available. The number of eggs deposited by the flies in each jar, however, is very much greater than that of the flies that eventually develop in it. The compe-

tition is very keen, and if the population of the box consists of two or more types with different adaptive values under the conditions of the experiment, the proportions of these types will change with time. To detect the changes, the populations are sampled at approximately monthly intervals. For this purpose, a jar with the culture medium is introduced into the box, and withdrawn in about 24 hours; some of the eggs deposited in it are transferred to regular culture bottles, and the larvae that develop are used to examine the chromosomes in the salivary-gland cells. To characterize the status of the population in a box at a given time, it has been found desirable to take on successive days 6 samples of eggs, and to obtain 50 chromosome determinations from each sample—300 chromosomes in all.

Experiments have been made with the populations in the boxes kept at temperatures from  $16.5^{\circ}$  to  $25^{\circ}$  C., with fresh food introduced from twice in three days to once in five days, with mixtures of all three chromosome types (Standard, Arrowhead, Chiricahua) or only two of them (Standard and Chiricahua), and with different initial frequencies of the different types. Experiments of this kind will have to be continued for at least another two years. The results obtained so far, however, are promising. Up to now, no systematic changes in the frequencies of the chromosomal types have been observed in the boxes kept at  $16.5^{\circ}$  C. But in every experiment carried at  $21^{\circ}$  C. or above (as well as at fluctuating room temperatures), the frequencies of the "Standard" chromosomes have increased with time to statistically significant extents. In contrast with this, the "Chiricahua" chromosomes have in all cases become reduced in frequency, sometimes strikingly so. The frequencies of the "Arrowhead" chromosomes

may remain constant or may be somewhat reduced.

These preliminary results prove beyond reasonable doubt that chromosomes with different gene arrangements found in populations of Mount San Jacinto produce physiological effects on their carriers, and are therefore subject to the action of natural selection. Many uncertainties, however, must be cleared away by further work. We can reproduce in the laboratory the changes that take place in the natural populations during the summer, but not those realized during the spring months. It remains to be seen whether the process of natural selection tends toward complete elimination, under laboratory conditions, of some chromosome types and their complete replacement by others, or whether the end result of selection is the establishment of a definite equilibrium of the competing types. Finally, nothing is known about the physiological effects of the different chromosome types that cause the latter to be favored, or discriminated against, by natural selection.

#### COLLECTING DROSOPHILA IN BRAZIL

Studies on the population genetics of *Drosophila pseudoobscura* in the western United States have emphasized the importance of the environment in which a species lives in determination of its genetic structure and of the evolutionary possibilities of the latter. As has been shown above, a cyclic, and apparently adaptive, reconstruction of the species genotype ensues in response to the seasonal climatic changes. It may be noted that seasonal climatic changes, everywhere in the temperate zone and in many tropical climates, also cause cyclic expansions and contractions of the population density of species that give more than a single generation per year. Such pulsations of the population density may have profound effects on the genetic

population structure and on population dynamics. But even regardless of the number of generations produced per year, any species living in temperate or cold countries is exposed, at different seasons, to profoundly different environments. A genetic variant which is very favorable during, for example, the summer season will be discriminated against by natural selection if it is unable to survive the winter. Only species with reaction norms versatile enough so that they feel at home in many different environments can exist in lands with sharp seasonal changes of climate. On the other hand, the relatively invariant tropical climates may favor perfection, rather than versatility, in the organic adaptation.

These theoretical considerations led to formulation of a plan of studies on the genetic structure of species that inhabit tropical countries, where the seasonal climatic changes are small, or at least appreciably smaller than in the temperate zone. An opportunity to initiate this type of research presented itself in 1943, during the writer's stay as a visiting professor at the University of São Paulo, Brazil, working under the auspices of the Committee for Inter-American Artistic and Intellectual Relations. The work was carried on in cooperation with Professor André Dreyfus, of the University of São Paulo, whose excellent hospitality the writer has pleasure in acknowledging.

A preliminary survey of the *Drosophila* fauna of the state of São Paulo and of the Federal District of Brazil was undertaken in cooperation with Mr. Crodovaldo Pavan, for the purpose of identifying species which are promising as materials for more intensive genetic investigation in the future. A total of 33 species have been bred in laboratory cultures. Of these, 6 species are semicosmopolitan forms, which occur chiefly in or close to human habitations. The other 27 species appear to be native,

and as many as two-thirds of them had to be described as new to science. There can be no doubt that the number of species living in southern Brazil is much greater than that named above; in fact, at least 60 species have been collected. Since, however, the purpose of the work is genetic rather than taxonomic investigation, only those species which have reproduced on the standard banana culture medium in the laboratory have been studied and described. Thanks to the unfailing kindness of Dr. Felizberto de Camargo, director of the Instituto Agronomico do Norte in Belem do Pará, the writer was able to work for about six weeks in the Amazon Valley. Not even a preliminary survey of the enormous *Drosophila* fauna of this region could be made in so short a stay, but some very valuable material was secured.

Among the 16 or more Brazilian species available in the laboratory, 3 species—namely, *Drosophila prosaltans*, *D. willistoni*, and *D. nebulosa*—have been chosen as promising material for further detailed work. It is hoped that enough mutant genes can be obtained in these species to bring their chromosomes under at least partial genetic control, which might permit an analysis to be made of their genetic population structure. This work program, planned to take several years, has been initiated in cooperation with Mr. B. Spassky. Aside from this relatively long-range plan, the material collected in Brazil presents many opportunities for interesting special studies. A preliminary report on one such study is given below.

#### SEXUAL ISOLATION WITHIN A SPECIES

It is known that representatives of different species do not mate at random, even if they occur side by side in the same territory. It is possible to demonstrate experimentally that if females of two species

are confined with males of one of them, the result usually is that a greater proportion of the conspecific than of the foreign females is inseminated. This preference for homogamic matings (like with like), and avoidance of heterogamic unions (between unlikes), has been observed almost entirely between representatives of distinct species. Yet any kind of difference found between species should, theoretically, be found—in at least a rudimentary or fragmentary form—within species as well. Some of the Brazilian species of *Drosophila* have distribution areas which extend north as far as Mexico and even the southern United States. Thanks to the courtesy of Professors J. T. Patterson and A. H. Sturtevant, the writer received several strains of *Drosophila willistoni*, *D. prosaltans*, and *D. sturtevanti* collected in Mexico and Guatemala. This furnishes an opportunity to test strains of the same species coming from geographically very remote localities, for possible sexual isolation between them.

Strains of *Drosophila willistoni* from different parts of Brazil (Belem do Pará, Rio de Janeiro, state of São Paulo) show no trace of sexual isolation. Males of any one of these strains, kept with females of their own and of another Brazilian strain, inseminate both kinds of females at random. If, however, Brazilian males are placed with a mixture of Brazilian and Guatemala females, more of the former than of the latter are inseminated. In a similar situation, Guatemala males either inseminate the two classes of females at random, or else give a statistically significant excess of inseminations of Brazilian females. There is, however, a strain collected at Teffé, state of Amazonas, Brazil, the flies from which refuse almost entirely to cross with any other *D. willistoni* strain, even if no choice of mates is available. When, exceptionally, cross-insemination does take place, viable offspring

are seldom, if ever, produced. A comparison of the Teffé flies with other strains of *D. willistoni* fails to disclose any external difference between them except for the slightly smaller body size of the Teffé flies. The only physiological difference so far noted is that *D. willistoni* flies begin to copulate sooner after hatching from pupae than do Teffé flies. Despite the lack of good external differences, Teffé flies belong to a species separate from *D. willistoni*. Because of the almost complete sexual isolation, gene exchange between populations of these species in nature must be absent or very slow. By the same criterion, the Guatemala and the Brazilian strains belong to the same species, *D. willistoni*; indeed, the deviation from randomness of mating between them is relatively small, and the mating preference, being one-sided, would not constitute an impediment to the gene flow from the Brazilian into the Guatemala race.

Strains of *Drosophila prosaltans* coming from the states of Guerrero and San Luis Potosí in México, from Guatemala, from Belem do Pará, and from the state of São Paulo in Brazil have been used. Males of each strain were kept for a certain length of time (3 to 4 days) with mixtures of females of their own and of other strains, after which all the females were dissected and their seminal receptacles examined under a microscope for the presence or absence of spermatozoa. The results can be stated as follows: The strains examined form a hierarchy in the order indicated above. If males of a strain high in the hierarchy are kept together with females of their own strain and of a strain lower in the hierarchy, homogamic matings are significantly, and often strikingly, more frequent than heterogamic ones. But when males of a strain low in the hierarchy are placed with females of their own and of a higher strain, heterogamic matings

exceed in frequency the homogamic ones. The Guatemala and Belem strains deviate from the behavior just described, to the extent that males of strains lowermost in the hierarchy (the São Paulo strains) inseminate their own females in preference to those of Guatemala and Belem. In other words, females of the high (Mexican) strains are inseminated preferentially, regardless of what kind of males are used in mixed cultures; but Guatemala, Belem, and São Paulo strains show a perceptible mutual repulsion. It may be noted that the deviations from randomness of matings increase hand in hand with the distances between the localities in which the strains were collected, Mexico and southern Brazil being the known extremes. The work on *D. prosaltans* has been carried on in cooperation with Mr. George Streisinger.

The strains of *Drosophila sturtevanti* employed in the experiments came from the state of San Luis Potosí in Mexico, from Guatemala, and from Belem do Pará, Rio de Janeiro, and the state of São Paulo in Brazil. The Rio de Janeiro and São Paulo strains interbreed at random; but with this exception any two strains show, when mixed, more or less clearly pronounced preferences for homogamic mating. Though the intensity of these preferences is usually smaller than the deviations from randomness of mating found in mixtures of *D. prosaltans* strains, yet the geographic races of *D. sturtevanti* are farther on the road to development of sexual isolation than are the races of *D. prosaltans*. This is so because a consistent mutual repulsion between representatives of different strains is found only as an exception in *D. prosaltans* (see above), and it is definitely the rule in *D. sturtevanti*.

Thus, mating preferences are met with not infrequently within species of *Drosophila*. Sexual isolation—i.e., a mutual

aversion to interbreeding—is, evidently, a special type of preferential mating. But, though various forms of preferential mating occur between races of a species, true sexual isolation is the rule where full-fledged species of *Drosophila* are concerned. Now, sexual isolation, like other forms of reproductive isolating mechanisms, prevents populations from exchanging genes. Natural selection will favor the establishment of sexual isolation (or of other reproductive isolating mechanisms) if the germ plasms of two populations have diverged so much that their mixing and recombination lead to formation of unfavorable genotypes. Natural selection can be effective, however, only if the populations upon which it acts contain genetic variants with which it can operate; natural

selection itself cannot produce such variants. The genetic factors which produce mating preferences between strains of a species, such as we observe in *Drosophila willistoni* and *D. prosaltans*, may be regarded as raw materials from which functional isolating mechanisms may arise through a process of natural selection. The situations found within the species *D. willistoni* (excluding the Teffé strain) and *D. prosaltans* are, if this hypothesis is correct, precursors of the sexual isolation which is observed in a rudimentary form in *D. sturtevanti*. An intensification of this would lead to the species splitting up into two or more daughter species nearly or completely isolated from each other by a mutual sexual repulsion, as observed between *D. willistoni* and the Teffé species.

## MAIZE GENETICS

BARBARA MCCLINTOCK

### COMPLETION OF THE STUDY OF THE ALLELIC RELATIONS OF DEFICIENCY MUTANTS

During this year studies were completed of 13 mendelizing recessive mutants associated with homozygous small terminal deficiencies of the short arm of chromosome 9. All 13 mutants arose independently following breakage of the short arm of a chromosome 9 which resulted, in each case, in deletion of a small terminal segment. Seven of these mutants gave a pale-yellow seedling phenotype (designated *pyd* 1 to 7) and six gave a white seedling phenotype (designated *wd* 1 to 6). A detailed description of these mutants, their method of origin, and the extent of the deficiencies was given in Year Book No. 42. Completion of these studies consisted in (1) verifying the allelic if not identical nature of all 7 *pyd* mutants, (2) verifying the allelic nature of all 6 *wd* mutants, (3) determining that all 7 *pyd* mutants were allelic to

and dominant over all 6 *wd* mutants, (4) determining that all 7 *pyd* mutants were not allelic to the recessive mutant *yg-2* (yellow-green plants), and (5) determining that all 6 *wd* mutants were allelic and recessive to *yg-2*. The results of the completed tests confirm the interpretation of the anomalous allelic relations given in the previous report.

### THE CHROMOSOME-BREAKAGE MECHANISM AS A MEANS OF PRODUCING DIRECTED MUTATIONS

The 7 *pyd* and 6 *wd* mutants intensively studied illustrate the repeated occurrence of phenotypically and genetically similar mutants following breakage of the short arm of chromosome 9. If large numbers of newly broken chromosomes 9 could be tested, many more *pyd* and *wd* mutants should appear. The following method was used to test 3287 newly broken chromo-

somes 9 for the presence of the *pyd* or *wd* deficiency mutants among these chromosomes: Large numbers of functional male gametes containing recently broken chromosomes 9 may be obtained by the method outlined in last year's report. Pollen with a large proportion of grains carrying a recently broken chromosome 9 was placed on the silks of plants possessing one normal chromosome 9 and one chromosome 9 with a female-transmissible long terminal deficiency. Whenever male gametes with recently broken chromosomes 9 are delivered by pollen tubes to female gametes, kernels with morphologically normal endosperms will arise when the female gametophyte contributes the normal chromosome 9. In contrast, aberrant endosperms will be formed when the female gametophyte contributes the chromosome 9 with a long terminal deficiency of the short arm. This is because the broken chromosome 9 delivered by the male parent undergoes the chromatid type of breakage-fusion-bridge cycle during the development of the endosperm tissues. This mechanism brings about deletions of terminal segments of the short arm of this chromosome 9 in some cells. Since the chromosomes 9 delivered by the female parent are already deficient for a long terminal segment, the telophase nucleus which receives this newly broken male chromosome 9 will be homozygous deficient for a segment of the short arm of chromosome 9. In such nuclei, the extent of the homozygous deficiency may range from minute to the full extent of the deficiency of the chromosomes 9 delivered by the female parent. Cells having any of these homozygous deficiencies are viable and capable of multiplication. Cells that are homozygous deficient for the longer deficiencies produce sectors within the endosperm that are aberrant either in aleu-

rone color development or in growth rates. These sectors are readily recognizable. It is possible, then, to select from an ear kernels that have received a deficient chromosome 9 from the female parent and a recently broken chromosome 9 from the male parent. In the recently broken chromosome 9 delivered to the zygote, the chromatid type of breakage-fusion-bridge cycle usually ceases in the young sporophytic tissues. The broken end no longer undergoes fusions, and the mitotic behavior of this chromosome is normal from then on. If this healed broken chromosome 9 has at least a full genomic complement of the short arm, green seedlings should arise from the embryos of these kernels. If it has a short terminal deficiency, either pale-yellow or white seedlings could appear. If it has a long terminal deficiency, the embryos homozygous for these longer deficiencies would be expected to be inviable. A total of 3287 seedlings was obtained from kernels that were classified by their endosperm appearance as having received a deficient chromosome 9 from the female parent and a newly broken chromosome 9 from the male parent. Of these seedlings, 77 were typical pale-yellow mutants in phenotype, and 48 were typical white mutants. Although tests for allelism of these 125 new mutants could not be made with the 7 *pyd* and 6 *wd* mutants intensively studied, the methods of origin and detection of these mutants make it difficult to conclude that they do not represent the repeated occurrence of phenotypically and genetically similar mutants. From the intensive study of the 7 *pyd* and 6 *wd* mutants alone, it is obvious that the chromosome-breakage mechanism is a means of independently inducing the same mutations time and again. In this respect, the mutation process is directed.

### CONTINUATION OF THE CHROMATID TYPE OF BREAKAGE-FUSION-BRIDGE CYCLE IN THE SPOROPHYTIC TISSUES

Among the seedlings which arose from the study outlined in the foregoing section, a type of behavior of the recently broken chromosome 9 delivered by the male parent was observed that had previously not been recognized. All the kernels from one ear that had received a deficient chromosome from the female parent and a recently broken chromosome from the male parent were planted under a single culture number. In many cultures, the green seedlings arising from these kernels were normal in appearance. In some cultures, a few seedlings were variegated for fine streaks of colorless, defective tissue. In a very few cultures, 20 to 30 per cent of the green seedlings were so variegated. All degrees of variegation were represented among these seedlings, some showing only a few small sectors of variegated tissue whereas others were variegated throughout. The kind of variegation strongly suggested that the chromatid type of breakage-fusion-bridge cycle had not ceased in the young embryo, but that the chromosome with the broken end was continuing this process into the sporophytic tissues. If this were true, just such variegation would be expected, because the chromatid type of breakage-fusion-bridge cycle would constantly delete segments from the short arm of the chromosome 9 delivered by the male parent. Since the chromosome 9 delivered by the female parent was already deficient for a relatively long terminal segment, nuclei—and thus sectors of homozygous deficient tissues—could be produced. These tissues should have chlorophyll abnormalities, since it is known that a homozygous deficiency for the tip of the short arm results in absence of chlorophyll. The tissues with the longer homozygous deficiencies

could be expected to grow at a slower rate than tissues with a full genomic complement. Thus, the fine streaks with chlorophyll modifications might represent these sectors of homozygous deficient tissues.

In most cases, the relative amount of variegated tissue diminished in the older leaves. Sectors of nonvariegated tissue were constantly arising as the plant developed. In no case was the whole plant variegated at the time of maturity. This suggested that the breakage-fusion-bridge cycle had ceased in the precursor cell or cells of these sectors, and that the broken end of chromosome 9 had healed and was no longer undergoing sister chromatid fusions.

Cytological examination of the anaphase figures in young leaves, in young shoots, and in the growing glumes of the florets, and of the meiotic division figures confirmed the interpretation. In those regions of a plant where it could be concluded that no variegation was occurring, no bridges at anaphase were found. In the parts of the plant where it could be expected that variegation for defective tissue was continuing, a single chromosome producing a bridge configuration at anaphase was observed in many figures. To determine whether a single chromatid bridge occurs in each mitotic figure, observations were made of the mitotic figures in the growing glumes of very young florets in those plants that showed very few recovered sectors (that is, nonvariegated sectors which arise following healing of the broken end in the precursor cell or cells that gave rise to the sector). Since healing of the broken end was rare in these plants, many of the mitotic figures in these glumes could be expected to show a bridge configuration at anaphase. Counts were confined to mid and late anaphases and to the very early telophase figures. Accurate observations of bridge configurations could not be made

in the earlier anaphases because of the crowding of the chromosomes in the spindle figure. The results are given in the following table:

Mid to late anaphase:

Single bridge	234
No bridge	77
Early telophase:	
Single bridge	92
No bridge	299

In many cases where a scoring of "no bridge" was made, it was obvious that a bridge had been present but had been broken by tension shortly before fixation had occurred. This applies particularly to the late-anaphase figures, although a number of such figures were observed at early telophase. Breakage of a chromatin bridge may occur at relatively early anaphase. However, breakage of the bridge may not occur at either the anaphase or the following telophase, for a fine chromatin bridge connecting two resting nuclei was frequently observed. The time of breakage of a bridge configuration may be related, in part, to the absolute length of the chromatin in the bridge. Among the different cells, this may vary from very short to very long. The time of breakage may likewise be governed, in part, by the length of the cell itself, which controls the extent to which the spindle may elongate. When the spindle axis is long, a short bridge may be broken early. When the axis is compressed, even a short bridge may not be broken in this spindle figure.

That it was the broken chromosome 9 contributed by the male parent which continued the chromatid type of breakage-fusion-bridge cycle, from the time of the first breakage at meiosis in the male parent through the gametophytic divisions and then through the consecutive sporophytic divisions, was shown by examination of pachytene configurations in these plants.

When the variegation continued into the microsporocyte tissues, the recognizable deficient chromosome 9 contributed by the female parent and a newly broken chromosome 9 contributed by the male parent were evident. The chromatin constitution of the short arm of the newly broken chromosome 9 varied, however, from cell to cell within the same anther. Various types of duplication, reduplication, deficiency, and deficiency plus duplication of the short arm were recognizable among the many microsporocytes examined. In these cells, the two sister chromatids of the newly broken chromosome 9 were fused at the position of the previous breakage, which occurred in the last premeiotic anaphase. This was evident from a study of the meiotic anaphases in those anthers where the breakage-fusion-bridge cycle had continued into meiosis. A single chromatid bridge *with no accompanying fragment* was present in many sporocytes, in either the first or the second meiotic anaphase. It could appear in the first meiotic mitosis if a crossover had occurred between one of the fused chromatids and a chromatid of the mitotically normal homologue. In the anthers examined, it most frequently appeared in the second meiotic anaphase, as shown by the table:

First meiotic anaphase:

Single bridge	20
No bridge	64

Second meiotic anaphase:

Single bridge in one cell of dyad	83
No bridge in either cell of dyad	25

In the second division anaphases, the dyads showing no bridge configuration usually gave evidence that a bridge had occurred in the first meiotic mitosis (for type of evidence, see McClintock, 1938). It may be concluded, then, that each sporocyte will show a chromatid bridge at a meiotic anaphase if it has received a chro-

mosome which was broken at the last pre-meiotic anaphase, provided that the broken end has not healed in the interim.

These studies of bridge configurations in somatic and meiotic mitoses strongly support the conclusion that a single chromatin bridge configuration will occur in every successive mitosis until the broken end is healed by some, as yet undetermined, cause. This healing may occur at any time. If the broken end had healed in one or more of the archesporial cells, clusters of sporocytes within an anther should show the same chromatin constitution of the short arm of the broken chromosome 9. This was observed in the pachytene examinations of a few of the anthers of the highly variegated plants.

It is now realized that it is possible for the chromatid type of breakage-fusion-bridge cycle to continue indefinitely. Most of the plants with chromatid bridges, however, appeared in only 4 of the 188 cultures. This suggests that some controlling genetic factors may be responsible for the continuation of the chromatid bridge cycle into the sporophytic tissues.

#### HOMOZYGOUS DEFICIENCY AS A CAUSE OF MUTATION IN MAIZE

*Methods of obtaining internal minute deficiencies.* It has been demonstrated that the recessive mutations *pyd* and *wd*, which are comparable in genetic behavior to typical recessive mutants, arise following deletions of small terminal segments of the short arm of chromosome 9. It has likewise been shown that deletions of small segments of chromatin in a region adjacent to the centromere of the short arm of chromosome 5 will give rise to visible mutations. A number of such mutants, which were repeatedly produced, have been identified. One of these exactly simulated and was allelic to the previously known recessive

mutant *bm-1* (brown midrib; see McClintock, 1941) and appeared when the *Bm-1* locus had been removed from the chromosome; that is, when the plant was homozygous deficient for the *Bm-1* locus. Selection of these two regions of the genomic complement for studies of homozygous deficiencies was purely a matter of chance and was governed by structural abnormalities which happened to occur in these two regions. It is reasonable to believe, therefore, that many mutations, distributed throughout the whole chromosome complement in maize, could arise as the consequence of homozygous minute deficiencies. Studies are now under way to test this hypothesis by subjecting the short arm of chromosome 9 to processes which could produce minute internal deficiencies within this arm of the chromosome. Several methods are being employed. One method utilizes the chromatid bridge cycle, which sometimes brings about the deletion of small internal segments of the short arm of chromosome 9. It has been observed that the tension on a chromatin bridge at a mitotic anaphase occasionally may result in breakages of this bridge at more than one position between the two centromeres. The fragments produced may or may not enter one of the telophase nuclei. Following this type of breakage, and following particular types of fusion of the broken ends in the succeeding nucleus, it is possible to obtain a chromosome 9 having an internal deficiency within the short arm. An internal deficiency may likewise be produced if the anaphase chromosomes are composed of two sister strands. When a bridge configuration is present, breakage of the two strands at anaphase may occur at a different position within each strand. If this is followed in the succeeding nucleus by fusion of the broken ends of the two unequal sister strands, and if a particular

position of breakage occurs in the bridge at the next anaphase, an internal deficiency may arise in one of the broken chromosomes. Should the broken end heal, a chromosome 9 with an internal deficiency could be isolated.

Since it is known that the chromatid type of breakage-fusion-bridge cycle may bring about internal deficiencies, mutations other than *pyd* and *wd* could appear in some of the seedlings which were grown to test the frequency of appearance of *pyd* and *wd* (as described in the second section of this report). In the cross that gave rise to these seedlings, the female parent contributed a chromosome 9 deficient for nearly one-third of the terminal segment of the short arm. The male parent contributed a chromosome 9 which had undergone the breakage-fusion-bridge cycle in at least the preceding gametophytic divisions. If this chromosome has an internal deficiency which lies within the range of the deficiency in the chromosome 9 contributed by the female parent, a seedling with a visible mutation could appear, provided that the homozygous deficiency allows viable tissues to be formed. An occasional seedling with an obvious mutation other than *pyd* and *wd* did appear among the 3287 seedlings. Some were viable and these mutants are now being tested to determine whether they are located within the short arm of chromosome 9 and whether they are associated with a visible structural modification of the arm. Other types, particularly those with defective chlorophyll, were inviable; but the isolation of such mutants for further study is being conducted by a method which is more laborious but which will insure their genetic perpetuation.

A very striking confirmation of the production of mutations other than *pyd* and *wd* by the chromatid type of breakage-fusion-bridge cycle was observed in the

plants that have a deficient chromosome 9 contributed by the female parent and a newly broken chromosome 9 contributed by the male parent, this newly broken chromosome 9 having *continued* the breakage-fusion-bridge cycle into the sporophytic tissues (see the third section of this report). In these plants, sectors of mutant tissue appeared. Such sectors are to be expected following structural modifications within the short arm of chromosome 9 which arise during the successive chromatid bridge cycles. Should a deletion of a small segment occur within the range of the deficiency in the female chromosome 9, and should this broken chromosome subsequently heal, a sector of homozygous deficient tissue could be initiated. As might be expected, many pale-yellow and white sectors were observed. Also, in some cases, the phenotypic characters of these sectors were similar to those observed in the new mutant seedlings mentioned above. Mutant sectors of the same phenotype were observed in different plants. This is to be expected on the basis of the hypothesis outlined, for the same mutant should appear whenever the same homozygous deficiency is present.

A second method of obtaining internal deficiencies in the short arm of chromosome 9 is based on the behavior of dicentric chromosomes 9. The dicentric chromosome is formed following the fusion of a broken end of the short arm of the chromosome 9 introduced by the female gamete with a similar chromosome 9 introduced by the male gamete. The behavior of this dicentric chromosome has been described in the two previous reports. Following a succession of the *chromosome* type of breakage-fusion-bridge cycle, the two broken ends entering a nucleus may heal and the two chromosomes 9 may be mitotically normal from then on. While this chromosome type

of breakage cycle is in progress, segments of the short arm are continually shifting their positions. This may result in the production of an internal deficiency in one or both of the healed broken chromosomes 9. If these healed broken chromosomes with internal deficiencies are male and female transmissible, it should be possible to obtain plants homozygous for these internal deficiencies. Mutations due to these deficiencies could then appear. New mutants other than *pyd* and *wd* have been isolated from the progeny of these plants. One of these mutants is phenotypically similar and genetically allelic to one of the mutants obtained by the chromatid type of bridge cycle outlined above.

*The repeated occurrence of the *yg-2* phenotype following chromosome breakage.* Other than *pyd* and *wd*, the most frequently recognized mutant arising from the chromosome and chromatid bridge cycles simulates in detail the phenotypic expression of the known recessive mutant *yg-2* (yellow-green plants). This mutant is located in the terminal chromomere of the short arm of chromosome 9. As stated previously, 77 *pyd* and 48 *wd* mutants appeared in the progeny of the 3287 seedlings derived from zygotes that had received a deficient chromosome from the female parent and a newly broken chromosome 9 from the male parent. There were, in addition, 6 yellow-green mutants. Four of these died following transplantation from the seedling bed, but 2 survived. Cytological examination of the chromosomes 9 in these 2 surviving plants showed that the male parent had introduced a newly broken chromosome 9 and that the female parent had contributed the chromosome 9 with the long terminal deficiency. No terminal deficiency was present, however, in the newly broken chromosome 9. When each of these two newly broken chromosomes was combined with

a chromosome carrying the normal *yg-2* mutant, yellow-green plants appeared. Thus, these two newly derived yellow-green mutants are allelic to *yg-2*. When combined with *wd*, both of the new yellow-green mutants gave yellow-green plants; in this respect, they are similar to *yg-2*. They also gave yellow-green plants when combined with each other. A third yellow-green mutant, derived from a dicentric chromosome 9 which had undergone the chromosome bridge cycle, behaved similarly in its phenotypic and genetic expressions. Furthermore, the typical yellow-green phenotype appeared as a recovered sector in plants starting development with a dicentric chromosome 9 and in plants with a deficient chromosome 9 and a chromosome 9 undergoing the chromatid type of bridge cycle. In several cases, these sectors extended into the sporogenous tissues, allowing the broken chromosome carrying the new yellow-green mutation to be isolated. At present, 7 new yellow-green mutants are being tested.

The relatively frequent and independent occurrence of mutants having the yellow-green phenotype suggests that they may be caused by a homozygous small internal deficiency. It is realized that many of the internal deficiencies which are male and female transmissible and which produce visible mutations when homozygous may not be cytologically recognizable. This is because the piece deleted may be too short for an accurate determination. Such deficiencies, however, *must* be produced by the chromosome and chromatid types of breakage-fusion-bridge cycles. Because of our accumulating knowledge that homozygous minute deficiencies will give rise to mutant phenotypes, it is expected that some of these deficiencies will produce visible mutations. Furthermore, the methods should produce the same mutation

time and again. This has been shown for *pyd* and *wd*, where the deficiencies are cytologically obvious, and for yellow-green mutants, where the deficiency may not be so easily detected. An intensive study of the chromosomes carrying these new yellow-green mutations will be conducted.

*Preliminary evidence suggesting that the bz phenotype may be simulated by a homozygous deficiency of the Bz locus.* The recessive mutant *bz* (bronze) described by Rhoades produces a "bronzing" of both aleurone and plant color. In the plant cells, the bronze character is due to the presence of brown pigment in addition to red or purple pigment. Only a small amount of purple or red pigment develops in the aleurone grains of endosperms that are homozygous *bz*. This mutant is located in the short arm of chromosome 9 between the mutant *C* and the centromere (Rhoades, unpublished). A chromosome 9 that had undergone the chromatid bridge cycle for several nuclear generations and is deficient for a total of approximately  $1\frac{1}{2}$  chromatides has been isolated. Two deficiencies are present in this chromosome: a small terminal deficiency, which gives rise to *pyd* when homozygous, and a longer internal deficiency located between *C* and the centromere. When this deficient chromosome was combined with a normal chromosome carrying *bz*, the bronze phenotype appeared in both the aleurone and the plant. This suggested that the *Bz* locus is included in the internal deficiency. The tests that have been conducted so far have shown that the bronze phenotype will appear when the aleurone and plant tissues are homozygous deficient for the internal deficiency of this chromosome. When this deficient chromosome, minus the *Bz* locus, is introduced into the primary endosperm nucleus by the female parent, and a newly broken chromosome 9 with *Bz* is introduced by the male parent,

an endosperm develops which is variegated for sectors of homozygous deficient tissues. This is due to the chromatid type of breakage-fusion-bridge cycle which the chromosome introduced by the male parent undergoes. This cycle constantly deletes segments from the short arm of this chromosome during the development of the endosperm. The sectors that are homozygous deficient for the terminal deficiency are completely normal in appearance, but the sectors that are homozygous deficient for the internal deficiency are similar in phenotypic appearance to homozygous *bz* if not indistinguishable from it. As yet, only one plant has been available to test the effect of the homozygous deficiency on plant color. This plant was variegated for normal and homozygous deficient tissues. In the limited regions where plant color developed, sectors of normal color (*Bz*) and sectors that were similar to the recessive *bz* phenotype were observed. The colored cells in normal (*Bz*) plants and in bronze (*bz bz*) plants were compared microscopically with the normal and the bronzelike sectors of the variegated plant. As far as these observations permit a judgment, the type of color modification in the homozygous deficient sectors of the variegated plant was similar to that in homozygous *bz* plants. Although the evidence is preliminary, it strongly suggests that the bronze phenotype may be simulated by a homozygous deficiency of the *Bz* locus. It is possible that the recessive mutant *bz*, or a deficiency of the *Bz* locus, exerts its effect on the interrelated anthocyanin-anthoxanthin synthesis in the cell. The investigations are being conducted in cooperation with Dr. M. M. Rhoades.

This deficient chromosome is transmitted normally through the female gametophyte. It is worthy of note that this chromosome with a relatively long total deficiency is partially male transmissible. Plants pos-

sessing one normal chromosome 9 and this deficient chromosome 9 produce pollen one-half of which carries the normal chromosome and one-half of which carries the

deficient chromosome. When this pollen was placed on silks of normal plants, 1092 of the 9689 functional pollen grains tested carried the deficient chromosome.

## POLYPLOIDY INVESTIGATIONS

H. E. WARMKE AND HARRIET DAVIDSON

### RUSSIAN DANDELION

Last year we reported preliminary studies indicating that roots of experimental tetraploid plants of the Russian dandelion, *Taraxacum kok-saghyz*, were heavier than those of corresponding diploid plants. More extensive comparisons, made during the course of this year, substantiate last year's findings and add data on relative water and rubber content.

Measurements of fresh and dry root weights, and of rubber percentages, were made on 55 diploid and 62 tetraploid plants. These were selected from as many different families as possible, so as to minimize the sampling errors in this genetically diverse material; only plants grown under similar conditions and of the same age were compared. Approximately one-third of the plants were grown in pots in the greenhouse; the others were grown in experimental plots out of doors.

The superiority in rubber yield of the tetraploid plants is clearly indicated in the accompanying table. The tetraploids have a significantly greater mean root weight and a slightly higher mean rubber percentage than the diploids. The water content of the two forms, as indicated by loss

of weight in drying, does not differ significantly.

### HEMP

*Marihuana studies.* Last year we were able to report that the drug content of hemp, *Cannabis sativa*, was slightly but significantly affected by one generation of selection. Now, after three generations, we can report important reductions in marihuana content in selected strains. The results are shown graphically in figure 1.

Tests were made on 264 plants, from 28 different cultures, whose parents, grandparents, and great-grandparents had been selected because of low drug content. These plants killed an average of  $3.00 \pm 0.12$  animals with our standard *Daphnia* assay (Year Book No. 42). One hundred and thirty-eight plants from 13 cultures, whose parents, grandparents, and great-grandparents had been selected because of high drug content, were also tested, and were found to kill an average of  $6.46 \pm 0.15$  animals. In terms of concentrations, these figures represent nearly a fourfold difference in marihuana content. The average difference between these strains is highly significant (Diff./S.E. = 18.21),

RELATIVE WEIGHT AND RUBBER CONTENT OF DIPLOID AND TETRAPOD ROOTS OF *T. KOK-SAGHYZ*

	No. plants	No. diff. families	Mean fresh root wt. (g.)	Range, mean fresh root wt. (g.)	Loss of wt. in drying (%)	Mean % rubber, dry roots	Range, rubber %, dry roots
2n.....	55	18	$8.88 \pm 0.91$	0.4 to 31.4	$73.26 \pm 0.66$	$2.14 \pm 0.26$	0.0 to 8.9
4n.....	62	16	$16.65 \pm 1.65$	2.35 to 56.5	$72.45 \pm 0.57$	$2.95 \pm 0.28$	0.0 to 7.1
Diff./S.E. ....	..	.	4.13	.....	0.90	2.13	.....

and would have been more so had not the limitation of concentrations used in the assay cut off the extreme high and low limbs of the curves (fig. 1).

It would be of great interest to know how the divergence of the two strains came about; but, because of modifications which have been introduced in the method of assay since its inception, it is difficult to compare accurately the present high-

as to make it of little value to the vendor of "reefers."

Tests have been made during the year, using pure chemicals and extracts of known marihuana activity, to determine the specificity of the *Daphnia* assay. Samples of a charas distillate of known physiological activity, of the active tetrahydrocannabinol acetate, and of the toxic but physiologically inactive crystalline canna-

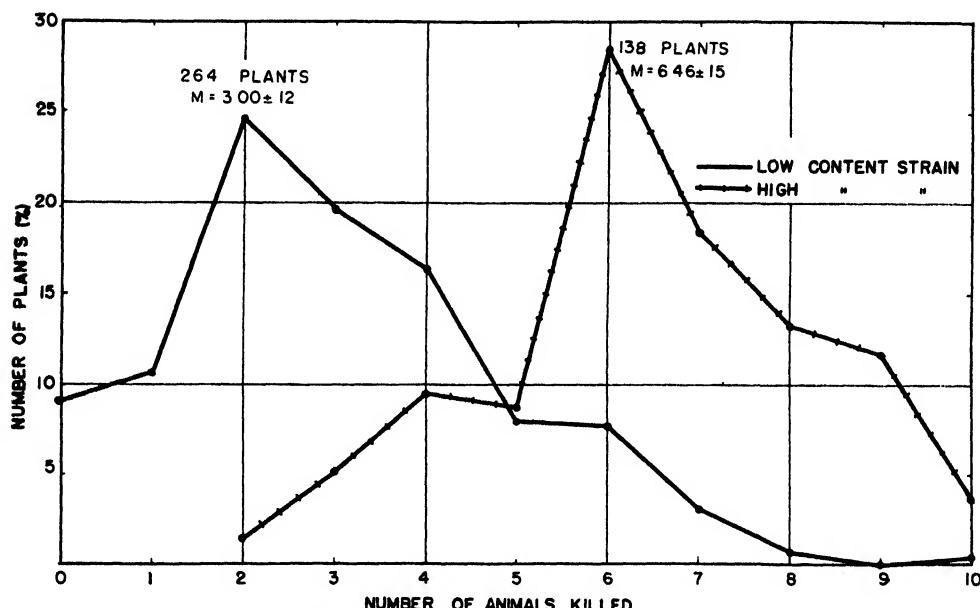


FIG. 1. Average marihuana potencies of high- and low-content strains of hemp after three generations of selection, as measured by the *Daphnia* assay. The difference of the means is highly significant (Diff./S.E. = 18.21).

and low-content strains with the unselected parental stock. It would appear, however, from such comparisons as are possible, that the divergence has resulted largely from a decrease in the drug content of the low strain; little, if any, increase appears to have been effected in the high strain. For this reason, leaf samples from the low strains are shortly to be sent to the Bureau of Narcotics to determine whether, even now, the drug content may be approaching a level so low

binol acetate were obtained from Dr. H. J. Wollner, of the U. S. Treasury Department. A sample of the active synthetic hexyl derivative of tetrahydrocannabinol was obtained from Dr. Roger Adams, of the University of Illinois.

These materials all were found to give strong positive tests with *Daphnia*. The fact that the crystalline cannabinol acetate is inactive on dogs and gives a strong positive test with *Daphnia* shows clearly that the *Daphnia* assay is not specific for

the marihuana drug. It doubtless will give a positive result with any acetone soluble compound within this toxicity range. This, however, does not reduce its usefulness as an assay method in a breeding program such as the present one. All compounds of known physiological activity that we have tested have given positive results, and this is the important consideration. In using the *Daphnia* assay, one measures any and all toxic substances in hemp leaves that are extracted with acetone, whether or not these have the specific marihuana activity.

The perfection of a reliable method of assay has made possible experiments designed to establish the place of synthesis of the marihuana drug and the importance of the drug in the metabolism of the hemp plant. Reciprocal grafts were made, at the ground level, between plants of hemp and hop, *Humulus lupulus*. Those combinations in which hemp stems were grafted onto hop roots failed, but the combinations of hop stems on hemp roots were successful and permitted assays to be made. Hop leaves from these unions were found to contain as much drug as leaves from intact hemp plants, even though leaves from intact hop plants are completely nontoxic. This indicates that hemp roots play an important role in the synthesis of marihuana. Whether or not they are the sole site of synthesis, as the roots of *Nicotiana tabacum* are in the synthesis of nicotine (Dawson, 1942), cannot be known until after the successful completion of the reciprocal hemp-on-hop grafts.

**Sex mechanism.** Studies on the sex mechanism of hemp, which have been under way for some time in this laboratory, are now ready for summary. The X and Y chromosomes in this species do not differ sufficiently in size to be distinguishable by routine cytological examination;

therefore, resort must be had to genetic analysis of polyploid ratios in such studies.

In diploid crosses, males and females appear in the progeny approximately in a 1:1 ratio (777:873). When diploid males and females are transformed into tetraploids by colchicine treatment, however, and then intercrossed, a ratio of approximately 7.5 females and female-hermaphrodites to each male (83:11) is found to result. Because of the appearance of the new class, 4A XXXY, a shift in the sex ratio in the  $F_1$   $4n$  generation is expected, and has been observed in *Melandrium* and *Silene*. In both these latter species, however, there was an excess of males and a deficiency of females.

There appear to be two possible explanations for the excess of females in the  $F_1$  tetraploid populations of hemp. Either (1) the XXXY class is female or female-hermaphrodite and not sharply distinguishable from the XXXX type (contrary to the observed cases in *Melandrium* and *Silene*, where this class is male or male-hermaphrodite); or (2) the female in hemp may be the heterogametic (XY) sex. In the latter case, the types XXXY and XXYY would be grouped together, as in *Melandrium* and *Silene*; but in this case they would be female and hermaphroditic, and the XXXX type would be male.

There is some cytological evidence (Mackay, 1939) and good genetic evidence (McPhee, 1925) that the female is not heterogametic in hemp. We have confirmed McPhee's results with our own stocks by selfing partially hermaphroditic diploid females and obtaining predominantly female progenies. The latter explanation for the excess of females among the first-generation tetraploid progenies, which requires the female to be heterogametic, would therefore appear unlikely.

If the first assumption is the correct

one, there should be two classes of  $F_1$   $4n$  females, XXXX and XXXY; and it should be possible to detect these types by the method employed to determine the heterogametic sex in *Silene otites* (Year Book No. 41). If XXXX individuals are crossed to XY males, only XXX and XXY individuals should appear in the offspring; no males would be expected. If XXXY individuals are crossed to XY males, the expected ratio is 1 XXX:2 XXY:1 XYY. It is likely that XXX and XXY types would intergrade, and thus yield a population of 3 females and female-hermaphrodites to each male (XYY).

Tetraploid females obtained directly by colchicine treatment (of necessity XXXX if the male is heterogametic) when crossed to diploid males have yielded 11 females and female-hermaphrodites and no males. Of a total of 31 triploid pedigrees obtained by crossing  $F_1$  tetraploid females (presumably containing XXXX and XXXY individuals in a ratio of approximately 1:6.5) with diploid males, 2 were found to be predominantly female (57 females and female-hermaphrodites to 1 male) and 29 had approximately 3 females and female-hermaphrodites to each male (677: 257).

Hemp, therefore, would seem to differ from *Melandrium* and *Silene* in having a different balance between male and female genes, such that XX, XXX, and XXXX individuals are female, XXXY and XXY individuals are female or female-hermaphrodite, and XY, XXYY, and XYY individuals are male.  $F_2$  and subsequent tetraploid generations presumably are composed of the offspring of XXXX and XXXY individuals crossed with XXYY males.

#### MELANDRIUM

The Y chromosome in *Melandrium* has been found occasionally to undergo spon-

taneous breakage in 2A XXY individuals, with the resulting formation of hermaphrodites in which growth of the male structures is arrested during late stages of development. A study of these aberrations is made possible in this material because any deficiency that arises in the Y chromosome is "covered" by a full set of genes in the accompanying X and thus may be transmitted to the offspring.

Young blossoms from a plant which has received a normal X and a deficient Y from one side (usually the female), and a normal X from the other, appear normal; both male and female structures are formed, and meiosis occurs in the regular fashion. Male development is arrested shortly thereafter, however; filaments fail to elongate, the anthers do not expand normally, and no viable microspores are produced. Female development is regular in such flowers, and a normal set of seed may be obtained if viable pollen from another source is applied to the stigmas. In some pedigrees these male-sterile hermaphrodites constitute as much as 18 per cent of the total number of hermaphrodites. Generally, however, they are less numerous and average only 2-3 per cent.

An examination of the chromosomes at meiosis in the young anthers of 32 of these modified hermaphrodites has revealed shortened Y chromosomes, which fail to synapse with either of the X's. The broken Y chromosomes are of different lengths in different plants; they range from Y's almost indistinguishable from normal in length to small spherical fragments the approximate diameter of an unbroken chromosome. These aberrant Y chromosomes are all centric and behave as univalents during the first meiotic division, and, if incorporated within nuclei, they divide in a normal fashion at the second meiotic division.

A cytological examination of the root tips of these same male-sterile plants has yielded more exact information as to the nature of the Y deficiencies. Usually one arm only is shortened; this may involve as little as one-fifth of the arm or larger segments, through gradual stages, to what appears to be the complete loss of the arm. In the roots, the small spherical fragments seen at first meiotic metaphase in the anthers prove to have both arms involved; one arm appears to be lost completely and the other reduced to about one-half. At the present stage of the investigation it is impossible to state whether these deficiencies are interstitial or terminal, although the latter appears probable. The length of the Y deficiency and the degree of abnormality are not linearly related. When the Y chromosome is only slightly shortened, the resulting plant is male sterile; larger deficiencies do not produce a more extreme effect. When the entire Y chromosome is absent, however, as in 2A XX plants, no male structures develop at all.

There would thus appear to be at least two regions in the Y chromosome which are of major importance in the development of maleness. One, which is proximal and present in the smallest observed fragments, is responsible for the initiation of anther and filament primordia, and carries male development through meiosis. The other is probably distal, and is responsible for elongation of the filaments and maturation of the pollen grains.

Problems of great theoretical importance still remain to be solved for a complete understanding of the sex mechanism in this species. Among these are: (1) The cause of the spontaneous aberrations of the Y chromosome, especially a determination of whether this breakage is associated with the process of synapsis and crossing over in the X and Y chromosomes. (2) The precise location of the important male-determining genes in the differential or homologous arms of the Y chromosome. (3) A resolution of the present dilemma concerning the behavior of the broken Y chromosome. That is, if one or more male genes are located in the homologous arm of the Y chromosome, why are they not exchanged with genes from the X during crossing over, thus causing a breakdown of the dioecious habit? If, on the other hand, these genes are located in the differential arm, why does a small deficiency there interfere with synapsis between the homologous arms of the X and Y chromosomes, as is seen to be the case? (4) Establishment of the number and location of genes in the X chromosome which govern the sequence of events in the development of femaleness. (5) Finally, an understanding of the mode of action and interaction of male and female genes, when brought together in the 2A XXY hermaphrodite in this species, which has evolved a strict separation of sexes in nature.

## MOUSE GENETICS

E. C. MACDOSELL, M. J. TAYLOR, AND T. LAANES

### LONGEVITY AND THE INCIDENCE OF LEUKEMIA

In contrast with the situation in non-leukemics, the lives of hybrid leukemic mice from mothers of the pure-bred non-

leukemic strain are lengthened as the mother's age at their birth increases (Year Book No. 42, p. 127). This finding has necessitated further study of longevity in relation to other variables appearing in the

data from the familiar second backcross experiment. In a still earlier report, based on a statistical analysis made by Dr. John Gowen, the major genetic influence on the incidence of leukemia was credited to inherited factors regulating the length of life, but it now appears that no such simple interpretation will stand. It is easy to record age at death and to apply statistical analysis, but to determine what is actually measured by longevity is a problem comparable in its complexity to determining what is measured by the incidence of leukemia. A long life may be due to natural or acquired resistance to the common causes of death, whether these are specific pathological entities or physiological weaknesses. At the other extreme, long life may be due to the avoidance of pathogens or physiological stresses. The incidence of leukemia will be modified by longevity factors that have specific action upon leukemia, and also by longevity factors that have specific action upon non-leukemic causes of death; but in the absence of all specificity, longevity factors will not modify incidence.

In this experiment longevity is modified by a diversity of variables, which bear diverse relations to the incidence of leukemia; namely, the parturition age of the mother, the strain of the nurse, sex, and, as previously recognized, the genetic constitution of the father. According to the current interpretation, the nongenetic longevity influence that varies with mother's age is specific for leukemia and acts by delaying the time of appearance of the disease, thus markedly modifying the incidence. The influence of one nurse strain is to delay death of male and female leukemics (which does not change the incidence of leukemia), and also to counteract certain non-leukemic conditions that appear in males (which increases the incidence of leukemia in males). The sex in-

fluence gives females greater resistance to certain causes of non-leukemic death, and so increases the incidence of leukemia among females; but this effect upon incidence seems to be partly counterbalanced by a slight resistance on the part of females to the appearance of leukemia. The genetic paternal influence upon longevity is nonspecific both for leukemia and for other causes of death, and so, resisting leukemia as effectively as other causes of death, does not modify the incidence of leukemia. This reverses the earlier interpretation and requires the assumption of other genetic differences between fathers that directly modify the incidence of leukemia.

How effectively the incidence of leukemia is influenced by longevity may depend on the strength of the genetic tendency; that is, on the number of potential leukemics. If the potential leukemics are few, a considerable differential change in length of life will make slight change in the incidence of leukemia; whereas, if the potential leukemics are many, the reverse may be true. Thus the longevity influence associated with mother's age has a striking influence upon the incidence of leukemia in families with strong leukemic tendencies, and virtually none in families with a very weak tendency. Much the same relation probably applies to the nurse-strain effect. A complete report of the second backcross experiment is ready for publication.

#### FOSTER-NURSING EXPERIMENT

In order to obtain confirmation of the nurse-strain and mother's-age effect on the incidence of leukemia, indicated in the second backcross experiment, two special experiments have been set up. The one on mother's age includes two sets of mice (all females), one from young mothers, one from old mothers. The mothers were

all from strain StoLi, and all nursed their own young; the fathers were all from strain C58, and each was mated to both young and old mothers. The breeding for this experiment has recently been completed.

In the experiment on foster nursing, two-thirds of the animals have died and been diagnosed by gross autopsies. Certain results are already so clear that a preliminary report seems desirable. The mice were first-generation hybrids between strains C58 and StoLi. Both strains were used as mothers. No mouse had a drop of its own mother's milk. Each litter was divided among foster nurses from three strains. The outstanding results are: (1) that, with nurses from the same strain, the incidence of leukemia is influenced by the strain of the mother; (2) that, with mothers from the same strain, the incidence of leukemia is influenced by the

strain of the nurse. These results appear within each sex, and the effects of the age of the mothers are largely balanced out. Within each nurse strain, C58 mothers gave more leukemia than StoLi mothers; within each strain of mother, StoLi nurses gave consistently a lower incidence of leukemia than Balb nurses. According to the present totals, C58 nurses are responsible for somewhat more leukemia than Balb nurses. The various combinations of mother and nurse strains show an amazing range of incidence, which considerably exceeds that attributable to genetic differences in the second backcross experiment. These results, in mice that are presumably all alike genetically, fully confirm previous findings, which indicated the nongenetic transmission of both maternal and nursing influences that in themselves appear to be under genetic control.

### ENDOCRINE STUDIES

O. RIDDLE, W. F. HOLLANDER, M. R. McDONALD, E. L. LAHR, G. C. SMITH, AND V. M. RAUCH

Much of the effort of this group during the year has been concentrated upon analysis and summarization of data obtained in three somewhat related long-term investigations. In summarizing the results of our extended study on heat production in races and hybrids of pigeons, we had, for some months, the able assistance of Professor Hoyt S. Hopkins, of the Department of Physiology, New York University. Miss Rauch resigned early in the year to assume duties at the San Mateo Naval Hospital. Since October Dr. McDonald has been a member of the group, and actively associated in an effort to clarify questions involving the relation of estrogens to the state and partition of calcium, phosphorus, and nitrogen in the blood.

The investigation of "constitutional factors" conducted by Riddle during the past

twenty-three years has involved two main procedures and techniques. First, the establishment by selective breeding of a series of "endocrine" races of doves and pigeons; inbreeding successive generations of these races, crossing the various races, and measuring or weighing various organs and certain functions in all individuals whether of pure race or hybrid. Second, the measurement of the rate of heat production in these races and hybrids; subjecting all available individuals of each type to measurement at high, medium, and low environmental temperatures at all seasons of the year. Data from this sixteen-year study have been analyzed, except for their correlation with organ-weight data which still await analysis. Though the analysis of data relating to breeding and organ weights is nearing completion, with

the special aid of Dr. Hollander, it is not yet possible to present final conclusions concerning this study of "constitutional

Several manuscripts dealing with earlier studies have been prepared and are now in press. Terminal data for studies on the

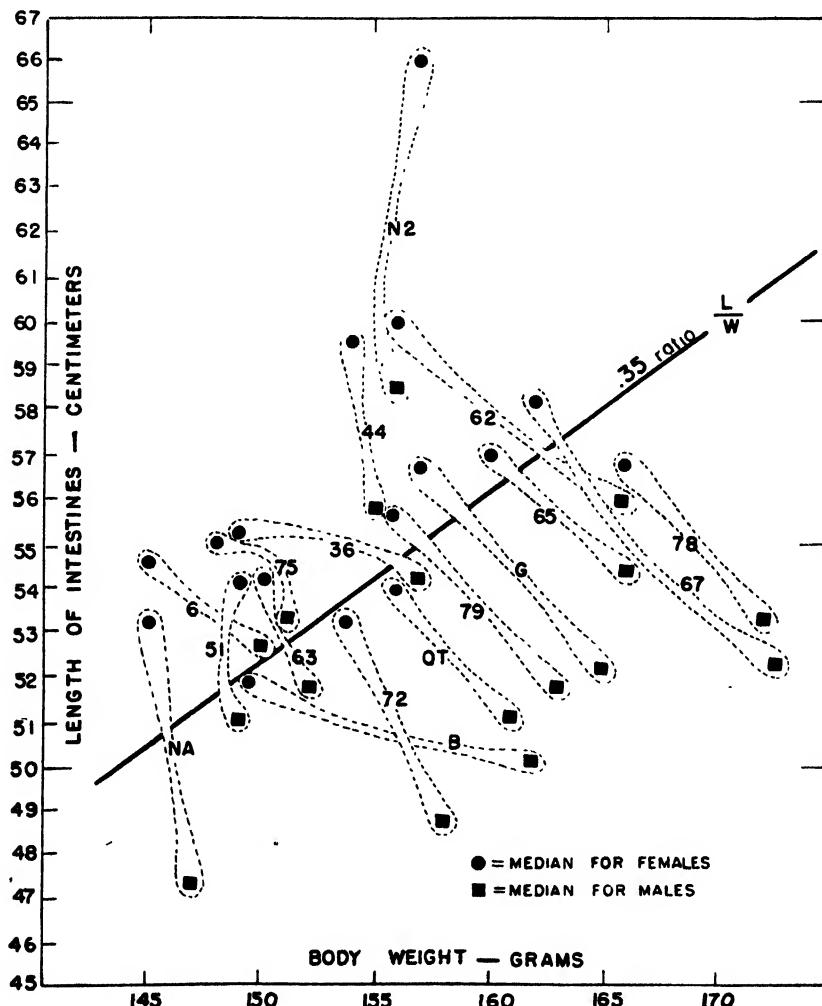


FIG. 2. Showing the segregation and persistence in offspring of constitutional factors for length of intestines in ring doves. Median intestinal length is always greater in females than in males of the same race, although, as is shown, the males are heavier. The races (NA, 51, 72, N2, etc.) were obtained by selective breeding, and the median values plotted include data from all healthy adults of the race reared during a subsequent period of 22 years.

factors." A graph which visualizes the successful segregation of unequal length of intestines in certain races, and also an association of longer intestines with the female sex, is shown in figure 2.

role of prolactin in maternal behavior are noted below. Despite the emergency period and effort devoted to summarization, our current research has yielded the data described in the following pages.

## HORMONAL REGULATION OF BLOOD CALCIUM AND PHOSPHORUS

Pigeons were the animals used in the studies which first showed (*a*) that the calcium of the blood is temporarily doubled in the females of egg-laying vertebrates when their eggs ripen, (*b*) that, coincidentally with this calcemia and ripening of eggs, the bone marrow of the long bones is temporarily replaced by solid, endosteal bone, and (*c*) that the injection of pure estrogenic hormones into either male or female birds leads to both calcemia and endosteal bone formation. This laboratory has considered it a duty to utilize its earlier experience in this field, together with parts of its pigeon colony, to assist in the solution of a group of problems which arise directly from the establishment of the above-mentioned facts. These problems relate primarily to the development and resorption of bone, but they are approached through studies on the partition and hormonal regulation of calcium and phosphorus in the blood, and thus on the share of the parathyroids and estrogens in these processes. The skulls of many of the birds which supplied data for our investigations are being utilized for studies on bones of the middle ear by Dr. E. P. Fowler at the Research Laboratory of the American Otological Society, New York City.

*Ability of estrogens to increase the "bound" calcium of the blood and to form medullary bone in the absence of the parathyroids.* A partial report on the first of these two items was made by Riddle, Rauch, and Smith last year. It was then noted that in tests made on 25 parathyroidectomized pigeons, the blood calcium was increased by estrogen to practically the same extent as in normal pigeons. Those tests have now been extended to 53 parathyroidectomized and 57 normal animals.

In truly comparable tests, treatment with estrogen increased the plasma calcium of 38 normal birds by 16.3 mg. per cent and that of 48 operated birds by 16.1 mg. per cent. The latter value, however, is subject to a reduction of 2.0 mg. per cent, since an increase of this amount resulted from the use of dihydrotachysterol to maintain life in the operated animals.

All the above-mentioned birds were further utilized in a test of the ability of estrogens to form medullary bone in the absence of the parathyroid glands. Though other investigators have shown that in various normal birds and mammals medullary bone develops following somewhat prolonged treatment with estrogen, it apparently has been taken for granted that the parathyroid shares in one way or another in the formation of this type of bone. For the first time this question was put to the test by the present study.

Individual birds were found to vary markedly in the amount of medullary bone formed within a unit of time under daily injections of estrogenic hormones. Suitable and adequate tests have shown, however, that the presence or absence of the parathyroid glands has no measurable effect on the amount of medullary bone formed in the femurs of these birds. The data which establish this conclusion cannot be condensed suitably for presentation here. In both normal and operated birds, the rate of bone formation during estrogen treatment (0.25 to 0.5 mg. daily) in these tests seems much slower than the rate at which ossification normally occurs just preceding the ripening of each pair of eggs. The rate of bone formation, however, is related directly to dosage. The daily injection of 0.5 mg. estradiol benzoate for 4 days induced even the lowest grade (grade 1) of ossification in only 20 per cent of 41 tests; one-half of that dosage over 8 days

gave only grade 1 ossification in all of 3 tests. A minimum of 15 days under high dosage (0.5 mg. daily) was required to produce in all birds ossification of grades 3 and 4.

The effects of diethylstilbestrol on blood calcium and bone were entirely similar to those obtained with estradiol benzoate. Two years ago Bloom, McLean, and Bloom reported that during November and December endosteal bone was not produced in male pigeons by estrogen dosage alone; at that season it was considered necessary to inject an androgen in addition. The larger dosage of estrogen used by us produced endosteal bone in both young and adult males at all seasons. When the androgen, androstenedione, was administered by us in large doses (3.0 mg. daily) over 15 days, it left the blood calcium unchanged; it showed no trace of effect on bone in 2 cases, and a minimum (grade 1) effect in 2 cases. This production of a minimum effect in some animals was probably due to the estrogenic potency of 45 mg. of this particular androgen.

Other conditions attending the ability of estrogen to act on blood and bone have been partly examined in immature males and females and in mature male pigeons. Removal of the anterior pituitary gland alone did not reduce or otherwise modify these actions in tests made on a group of 6 birds. Both pituitary and parathyroids were removed from 9 birds, but in such birds life could not be maintained sufficiently long for adequate tests of the ability of estrogens to form bone. During recent months pigeons have been maintained after simple parathyroidectomy without feeding extra calcium and without administration of dihydrotachysterol (AT10). This was done by daily administration, by mouth, of 1 gram of aluminum hydroxide (gelatinous). The absorption of phosphorus from the alimentary tract is

thus greatly reduced, and the parathyroid-ectomized birds remain in excellent condition. This result, like some earlier results obtained by other workers on mammals and man, suggests that parathyroid function relates more directly to the metabolism of phosphorus than to that of calcium.

The same operated and normal birds which were used in the studies described above were further utilized by Riddle and McDonald for a special study of the ultrafiltrable (ionized) calcium and the inorganic phosphorus of the blood. Neither of these fractions seems to have been measured hitherto in parathyroidectomized birds. And, though ultrafiltrable calcium has been shown to change very little in birds which increase their total blood calcium in the normal manner—i.e., at egg laying—we have no information concerning the behavior of this form of calcium when the total calcium is increased by the injection of a pure estrogen. The question involved is important to decisions relating to the precise role of hormones in the regulation of blood calcium, since it has not yet been proved that estrogen alone is involved in the calcemia which occurs at egg laying. Results of this study show that estrogen treatments over periods of 3 to 15 days either leave the ultrafiltrable calcium unchanged or increase it by less than 1.0 mg. per cent in normal, parathyroidectomized, and hypophysectomized pigeons. In these same tests the "bound" calcium was frequently increased by 18.0 to 45.0 mg. per cent. Some birds deprived of their parathyroids died in tetany, with ultrafiltrable calcium much reduced, despite estrogen treatment and increased total calcium. These data apparently prove that estrogen has little or no ability to increase the ultrafiltrable calcium of the blood in normal pigeons, and that it cannot maintain this

fraction of the blood calcium at a normal level in parathyroidectomized pigeons.

The behavior of the inorganic phosphorus of the blood was also determined in this valuable series of parathyroidectomized and estrogen-treated pigeons. This operation, as earlier observed in various mammals, increased plasma inorganic phosphorus, in a total of 15 tests in young birds, from 5.04 to 7.33 mg. per cent, and in a total of 11 tests on adult birds from 2.99 to 7.56 mg. per cent. Many tests demonstrated that injections of estrogen, but not of androgen, also invariably increase the plasma inorganic phosphorus in groups of young and adult pigeons, both normal and parathyroidectomized.

*Effects of estrogens on blood calcium and phosphorus in rabbits.* Groups of rabbits were injected either with estrone, estradiol benzoate, or whole anterior pituitary extract, or with the control substances, sesame oil, propylene glycol, and muscle extract. Six rabbits were implanted with 2 pellets each of estradiol benzoate. Samples of 4 cc. of blood were drawn just before injection, at 4 and 24 hours later, and also after 3 and 7 days. On 150 samples, determinations were made of total plasma calcium, inorganic and organic phosphorus, and protein nitrogen.

In these tests changes in protein nitrogen provided an index of dilution of the blood due either to sampling or to the voluntary fasting which often accompanies the injection of some of these substances into rabbits. Hemodilution was evident in most of the 4-hour samples, and in all samples obtained from rabbits injected with 3.0 mg. estrone or 50 mg. whole anterior pituitary extract. Not only did these two last-named substances fail to increase the plasma calcium and inorganic phosphorus, as they do in pigeons, but the observed decrease was greater than can be accounted for by the observed hemodilution. The 11 rabbits

which received injections, or "pellet implants," of estradiol benzoate showed little hemodilution (largely limited to 4-hour and 24-hour samples), a slight decrease of plasma calcium, no change in inorganic phosphorus, and a very marked decrease of organic phosphorus.

The average decrease of organic phosphorus in 15 rabbits treated with estrogen for 7 days was 28 per cent of the normal value; and the decrease was greatest (33 per cent) in rabbits given heaviest (3.0 mg.) dosage. Anterior pituitary extract produced no change (less than 2 per cent) at 7 days in 4 rabbits, though a drop of 28 per cent was observed in the 4-hour samples. "Control" substances (muscle extract, sesame oil, propylene glycol) injected into 11 rabbits were associated with a decrease of organic phosphorus of 17 per cent in 4-hour samples, but of only 3 per cent in 7-day samples. It is evident, therefore, that prolonged estrogen treatment of rabbits which are frequently bled does not yield results on total calcium and inorganic phosphorus that are in any way comparable with those obtained in pigeons; moreover, in rabbits this treatment resulted in a marked reduction of the organic phosphorus of the blood both with (4 tests) and without (11 tests) detectable reduction of plasma inorganic phosphorus. There is a possibility that estrogen treatment in these rabbits (4 to 6 months old) led to rapid depletion of the blood calcium and phosphorus through the formation of endosteal or other bone. This point was not covered by our tests.

*The partition of calcium, phosphorus, and nitrogen in the blood plasma of the pigeon.* This laboratory previously showed that the plasma calcium of female pigeons is more than doubled at or near the time eggs are ovulated, and also that estrogens will cause similar or even greater increases of the plasma calcium in mature or im-

mature birds of either sex. In these cases the increase in plasma calcium is mainly in the nonultrafiltrable fraction, and the substance or substances with which the "bound" calcium is united is not definitely known. Exact knowledge on this point is highly desirable; and McDonald and Riddle have made progress in an investigation of this problem. The bond between the calcium and the unknown binder or binders was found to be very unstable, being broken by such mild treatment as dilution of the plasma with water. Early attempts to isolate the "bound" calcium compound or compounds by the chemical methods available were therefore soon dis-

eggs ripen in the ovary, and since it has been rather generally accepted that most of the nonultrafiltrable calcium fraction of normal mammalian plasma is bound to the plasma proteins. The changes in these various compounds have been studied (*a*) in females during the normal reproductive cycle and (*b*) under the influence of estrogens (in normal, hypophysectomized, and parathyroidectomized pigeons of both sexes, old and young), with the expectation that some outstanding correlations would be found. The study has not been completed, but the results obtained to date are informative.

The table summarizes measurements of

THE PARTITION OF CALCIUM, PHOSPHORUS, AND NITROGEN IN THE BLOOD PLASMA OF FEMALE PIGEONS  
WITH RESTING OVARIES AND AT 36 HOURS BEFORE OVULATION  
(Averages of 5 to 10 determinations)

Plasma substance	Reproductive rest (mg. per ml. plasma)	36 hours before ovulation (mg. per ml. plasma)
<b>Calcium:</b>		
Total.....	0.106	0.278
Ultrafiltrable.....	0.066	0.061
Nonultrafiltrable.....	0.040	0.217
Colloidal.....	0.014	0.082
Nonultrafiltrable-noncolloidal.....	0.026	0.135
<b>Phosphorus:</b>		
Total.....	0.282	0.676
Lipid.....	0.234	0.428
Protein.....	0.009	0.169
Acid-soluble organic.....	0.005	0.005
Inorganic.....	0.030	0.066
Ultrafiltrable inorganic.....	0.023	0.024
Nonultrafiltrable inorganic.....	0.007	0.042
<b>Nitrogen:</b>		
Nonprotein-nonlipid.....	0.25	0.26
Protein.....	4.70	6.05

continued. The problem was then attacked by examining simultaneously the various calcium, phosphorus, and nitrogen components of the plasma. This procedure seemed logical, since it was known that by *ie* of the plasma phosphorus components also increase at or near the time phosph

the extent of change in the above-named plasma components when "resting" ovaries become active and are within 36 hours of the release of an ovum. These two points in the reproductive cycle are here arbitrarily selected for presentation, since it is found that they represent the periods of

minimum and maximum concentration, respectively, of plasma calcium. It is especially noteworthy that the changes observed in the table have been reproduced, in birds of all ages, sexes, and operated types, by 4 to 15 daily injections of estrogen.

Apparently no significant change occurs in the ultrafiltrable calcium, ultrafiltrable phosphorus, acid-soluble organic phosphorus, and nonprotein-nolipid nitrogen either during normal reproductive activity or following treatment with estrogen.

Both nonultrafiltrable calcium and nonultrafiltrable inorganic phosphorus increase greatly at ovulation. When these components are plotted against each other, for females in all phases of reproduction and also for all ages, sexes, and operated types following estrogen injection, there appears to be a direct relation between the rise in nonultrafiltrable calcium and that in nonultrafiltrable inorganic phosphorus. Earlier workers have suggested, on the basis of data obtained from the plasma of laying hens and from mammals with experimental hypercalcemia, that the nonultrafiltrable inorganic phosphorus is in the form of "colloidal" calcium phosphate. This view is supported by a correlation coefficient of  $0.960 \pm 0.014$  obtained for 32 estrogen-treated birds, both normal and operated.

At present there is no direct method for determining the composition of the colloidal calcium phosphate. Indirect methods in other laboratories have yielded the formula  $\text{Ca}_3(\text{PO}_4)_2$ . On the assumption that this is correct, values for colloidal calcium have been calculated which show that about one-third of the nonultrafiltrable calcium is in this form. Subtraction of the colloidal calcium from the total nonultrafiltrable calcium gave values for that portion of the "bound" calcium still unaccounted for.

The slight increase found in the total plasma proteins at or near ovulation (and following injections with estrogen), in comparison with the large increase in nonultrafiltrable-noncolloidal calcium observed in those plasmas, makes it improbable that the calcium is bound indiscriminately by all the plasma proteins. It seems more probable that the particular phosphoprotein, serum vitellin (which increases so markedly simultaneously with the increase in the nonultrafiltrable-noncolloidal calcium), has a much greater calcium-binding capacity than the usual plasma proteins. This view is supported by the data of figure 3, in which the serum vitellin, as measured by protein P, is plotted against the nonultrafiltrable-noncolloidal calcium. Data for every bird studied to date are included in the graph. Very much better correlation was obtained in this plot than when this calcium fraction was plotted against the total plasma proteins or the lipid phosphorus.

During the course of this investigation it was noted that about 30 per cent of the substances ordinarily considered plasma proteins had the unusual property of being soluble in mixtures of 75 parts absolute alcohol and 25 parts absolute ether adjusted with trichloracetic acid to pH 1-2; this fraction was only partially soluble between pH 2 and pH 7, and insoluble in similar mixtures at a pH more alkaline than 7. The proteins of both (heparinized) rabbit and human plasma were found to behave in a similar fashion. Whether this is a peculiar property of one or many of the plasma proteins, or is due to their combination with heparin, remains to be determined.

#### ESTROGENIC ACTION ON OVIDUCTS

In Year Book No. 37 Riddle and Lahr reported the earliest results from their

utilization of the threadlike oviducts of young ring doves (1.5 to 2.5 months after hatching) for the simultaneous study of three questions: (a) the relative estrogenic potencies of some of the more common steroid hormones, including androgens;

dictated by two or three items taken from the results. Control oviducts, 134 in number, weighed  $19.4 \pm 0.7$  mg. Seven daily doses of 0.001 mg. of diethylstilbestrol produced oviducts weighing 175 mg.; and a total dose of 0.07 mg. over a period of 7

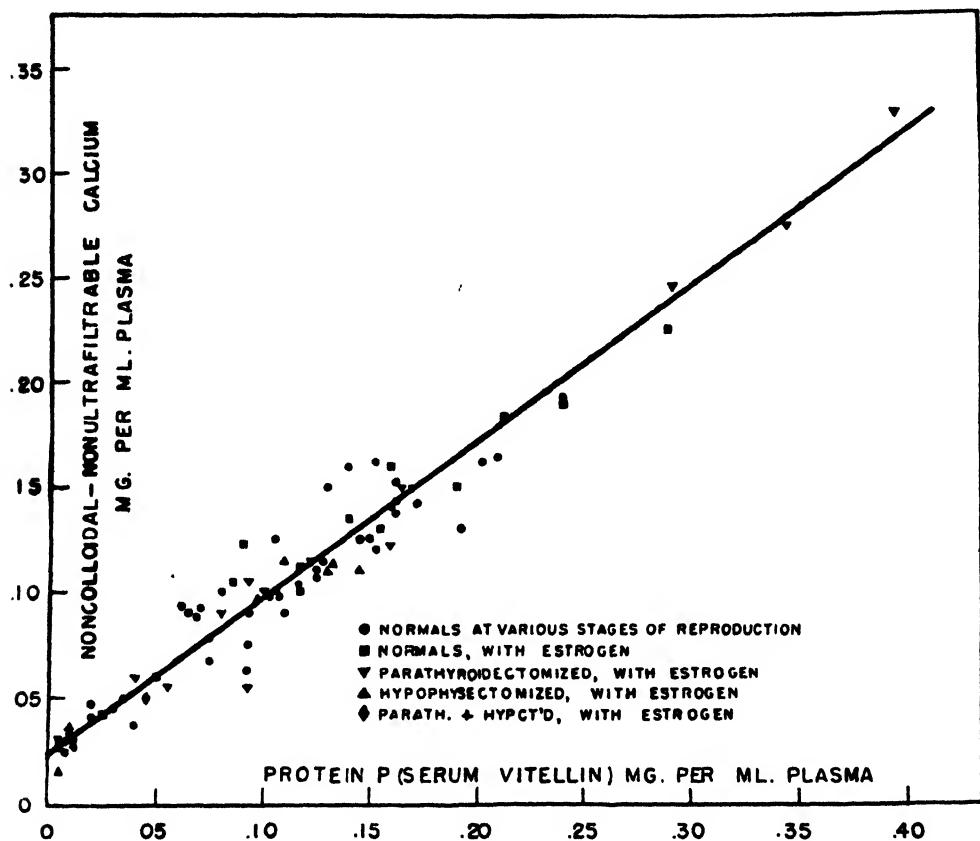


FIG. 3. Plot of the nonultrafiltrable-noncolloidal calcium against the serum vitellin of the blood plasma of pigeons at various estrogen levels, showing that there is a direct correlation between these two components of the plasma.

(b) the effect on the growth response of the oviduct of varying the volume of fluid injected; (c) the synergistic or antagonistic effect of simultaneously injected estrone and progesterone on growth of the oviduct.

The sensitivity of the undeveloped oviduct to estrogenic stimulation may be in-

days produced oviducts weighing 822 mg. Results obtained from the treatment of 255 immature female doves with steroids at various levels of dosage, and with volume of fluid varying from 0.1 to 0.3 cc., have been summarized as follows: (1) The concentration of estrogens in minimum quantities of sesame oil decreased

the effectiveness of these hormones. (2) The relative estrogenic potency of the several steroids tested is shown in the accompanying table. (3) The injection of pro-

lactin to obtain evidence on the question of whether or not the effective steroid hormones produce their effects by causing prolactin to be released from the animal's own

APPROXIMATE RELATIVE POTENCY OF VARIOUS STEROIDS IN STIMULATING INCREASE OF WEIGHT IN THE OVIDUCTS OF IMMATURE RING DOVES  
(Diethylstilbestrol is given an arbitrary value of 10,000)

Substance	Relative potency	Substance	Relative potency
Diethylstilbestrol . . . . .	10,000	Dehydroandrosterone . . . . .	2
Estradiol benzoate . . . . .	3,500	Testosterone . . . . .	2
Estradiol . . . . .	800	Androsterone . . . . .	2
Estrone + progesterone . . . . .	1,000+	Desoxycorticosterone acetate . . . . .	(2?)
Estrone . . . . .	600+	Pregnaneolone . . . . .	0.6
Progesterone . . . . .	10	Cholestenone . . . . .	0.0
Androstenediol . . . . .	10		

gesterone enhanced the growth-promoting effect of estrone on the dove oviduct by 60 to 70 per cent. (4) None of the steroids used showed any ability to promote growth in ovaries of treated birds. The estrogens gave evidence of ability to retard or suppress growth in the ovaries.

#### MATERNAL BEHAVIOR

The last of a series of studies by Riddle and associates on the share of hormones in the regulation of broodiness and maternal behavior in fowls, rats, and doves has been completed; the results have been analyzed and are in process of publication. In earlier studies of the series it was shown that: (a) prolactin induces broodiness in laying fowls; (b) prolactin and certain steroid hormones are capable of initiating maternal behavior in rats of both sexes; (c) an increased rate of mitosis in the crop-sac epithelium (indicating increased release of prolactin from the pituitary) occurs in doves and pigeons at the precise time that these birds become "broody" in a natural manner. As partly reported last year, Riddle and Lahr have utilized doves in an

pituitary gland. The results have been summarized as follows:

Ring doves of both sexes and of three age levels were used to test the ability of implanted pellets of certain steroid hormones to induce broodiness and to release prolactin from the pituitaries of the treated birds.

Seventeen untreated pairs of mature or adolescent doves served as controls; these, together with 5 pairs treated with pellets of estrone (total of 44 birds), did not become broody nor did their crop sacs increase in size.

Paired adult and adolescent birds of either sex treated with progesterone or desoxycorticosterone acetate, and similar females treated with testosterone propionate, became broody in 43 of 62 tests. Twenty-one of these broody birds were killed while broody, or while feeding young, and proof of enlargement of their crop sacs was obtained by weighing these organs; 29 of these responding birds fed or reared young, thus proving both the functional state of their crop sacs and the antecedent release of prolactin under the

stimulus of the effective steroids. These steroids were nearly or quite ineffective in young doves and in isolated (unpaired) mature doves.

Those steroid hormones which were earlier observed by Riddle, Lahr, and Bates to promote maternal behavior in rats were here shown to be effective in inducing broodiness in doves. This effect in doves was produced by steroids which caused a concurrent release of prolactin from the dove's own pituitary, but not by steroids which failed to do so. These results provide further evidence of a direct and specific role of prolactin in the development of an instinct—broodiness and parental care.

#### HEAT PRODUCTION AFTER FASTING AND HYPOPHYSECTOMY

In an earlier report we recorded the fact that measurements made by Smith and Riddle apparently indicate that removal of the pituitary gland, plus fasting, reduces the basal metabolism of pigeons less than does fasting alone. That result was unexpected, since hypophysectomy alone, like fasting alone, was earlier shown to cause a marked reduction of the basal metabolism of adult pigeons. The study has now been completed, and analysis of the data leads to the following conclusions.

Repeated measurements of the respiratory exchange were made under basal conditions, at both  $25^{\circ}$  and  $30^{\circ}$  C., on 43 normal and 37 hypophysectomized young Carneau pigeons subjected to a 10-day fast. Neither prolonged fasting nor hypophysectomy caused any apparent shift of the zone of thermal neutrality.

Fasting was accompanied by a moderate acetonemia, by a slight reduction of both liver and muscle glycogen below the 24-hour fasting level, by little or no change in the total store of liver fat, and probably by

no decrease in total reducing substances in the blood.

Respiratory quotients of 0.63 to 0.68 were frequently obtained from both types of birds that had fasted for 48 or more hours; a few quotients of 0.74 to 0.79 were obtained to the end of the fast. The many low quotients obtained in these tests on pigeons, together with available information from earlier studies on fowls, support the view that birds tend to produce quotients lower than 0.69 from combustion of their own protein.

The caloric value of oxygen utilized in the burning of protein by birds has not been determined with acceptable accuracy. On the assumption that the oxygen used had a value of 4.686 calories per liter, irrespective of the respiratory quotients obtained, the heat production of 39 normal pigeons was reduced from a 24-hour fasting value of 4.33 to 3.10 calories per kilo per hour; this is a reduction of 28.6 per cent of the basal value by 9 additional days of fasting. Hypophysectomized fasting pigeons showed a comparable decrease of only 22.3 per cent.

#### BREEDING PROCEDURES

Propagation and breeding tests with some of the more interesting races and types of pigeons and doves are being continued by Hollander and Riddle. It was noted last year that the "ataxia" character is being recombined and preserved in a more vigorous stock by crossing with White Carneau. An apparent or probable case of linkage has appeared in connection with this cross of the ataxic and Carneau breeds. The backcross segregations, from female hybrids, have given 21 non-crossover and 9 crossovers between ataxia and "grizzle," the latter being a dominant color factor from the White Carneau.  $F_2$  data are consistent also in showing a tendency

to linkage. Ataxia shows simple recessive inheritance, and it has now been observed that variability of the trait is notably af-

fected by the bird's state of health. Even slight illness exaggerates the manifestation of ataxia.

## ANTHROPOLOGY AND HUMAN GENETICS

MORRIS STEGGERDA AND HILDA H. WHEELER

### ANTHROPOMETRY

So far, very few scientific studies have been made on the anthropometry of the Navajo Indians. In 1932 Dr. Steggerda began an anthropometrical study of the Navajos living on the reservations of Arizona and New Mexico. He has now completed the field work for this study.

The average age of the 150 adult males investigated was approximately 24.5 years, and that of the 100 females 22 years. The principal measurements were tabulated and discussed in Year Book No. 42 (1942-1943). In addition, span—a measurement not generally taken by anthropometrists because of the probability of errors arising from lack of uniformity in the technique used—was recorded by the author and found to be very constant. The means found for this dimension are 174.56 cm. for males, and 160.32 cm. for females. The relative span of the Navajos averaged 103.98 per cent for males and 102.85 for females.

The mean head length of the Navajo may be considered rather short when compared with that of whites and Negroes measured by the author. It is 184 mm. and 177 mm. for males and females respectively. Head width for Navajos averaged 156.93 mm. and 151.04 mm. for males and females respectively. The cephalic index was found to be 85 per cent for both males and females. The Navajos are very round-headed, as compared with American Indians as a whole. These broad-headed Indians are confined more or less to a restricted area in both North and South

America. Indians with a cephalic index of 80-84 per cent are the general rule; they extend over all of North America, most of Mexico, and a large part of South America. Longer-headed Indians (76-80 per cent) are found in the eastern part of North America; and there are small groups in Mexico and in the south central part of South America.

Rates of growth at various stages in the development of Navajo children were studied over a 10-year period. Seventy-five females and 100 males were investigated, and their growth compared with that of other racial groups. From the comparisons made it appears that Navajo Indian babies are smaller at birth than white babies. Birth weights were taken by registered nurses in two excellent mission hospitals on the Navajo reservation. As has been previously reported, it is shown conclusively that the weights of Navajo boys are considerably less for any given height and age than the usual weight predictions for whites. This is true also for girls up to 13 years of age, after which the Navajo girls become heavier than white girls. It was found also that in three races—Navajo, white, and Negro—the age at which the curve for stature for females crosses the male curve is practically the same.

Data indicating that both the height and the weight of the Navajo children were greater for each age in 1941 than in 1932-1934 were presented in Year Book No. 41 (1941-1942).

This study on the anthropometry of the Navajos also includes a table showing the average number of carious and missing

teeth in the adult series. It was found that of the 150 adult males, 65 individuals, or 45 per cent, had all teeth in perfect condition, as compared with 39 per cent of the women. These percentages are very much lower than those found for the general adult white population.

#### ETHNOLOGY

During the year two papers were published dealing with certain aspects of Dr. Steggerda's previous work in Yucatan. The first of these describes thirty towns in Yucatan, showing that they resemble each other in pattern, yet differ in many respects. The region of Tizimin, for example, supports a heavy growth of trees, and lumber is the most important product there. In this region of high trees, the dominant fauna are jaguars, snakes, and birds. When the bush is cleared, beans are commonly grown in this area, in contrast with the more arid parts of northwestern Yucatan, where henequen is the principal crop. In regions where clay is to be found, such as Uayma and Ticul, pottery making is the chief means of support. Towns along the railroads are supported largely by industries connected with the railroad, such as cutting wood for the wood-burning trains and wooden ties for the tracks. Many of the towns described—for example, Merida, Valladolid, Motul, and Izamal—are built on the ruins of ancient Maya cities.

The second study was made to determine whether the modern uses of plants in Yucatan are the same as those of the seventeenth and eighteenth centuries. The results are reported in Year Book No. 37 (1937-1938). Several samples of plants used for medicinal purposes were chemically assayed to determine their possible scientific value. *Acromia mexicana* (called *tuk* in Maya) and *Tacoma stans* L. (*x-kan-lol*) are said by the Maya to be beneficial

in the treatment of diabetes. Samples from the roots and central stem of the first and the roots of the second were clinically assayed and found to be inert. Likewise, the seeds of the *ramon* tree, *Brosimum Alicastrum* Sw., were assayed. They are said by the Maya to contain a milk-producing agent for nonlactating mothers, but failed to produce any reaction when fed to nonlactating laboratory animals.

#### SOCIOLOGICAL ANTHROPOLOGY

A comprehensive study of the status of the teaching of physical anthropology in colleges in the United States during the school year 1940-1941 was completed and published this year in cooperation with Dr. Earl W. Count, of the Department of Anatomy, Flower and Fifth Avenue Hospitals, New York City. This investigation appeared to indicate that the American people are very much interested in certain pragmatic aspects of human biology. They are not interested, certainly not vitally so, in the comprehensive study of animal man. Until there is more demand from undergraduates for such study, the colleges and universities will not provide it; until they provide it, there will not be any great number of students engaging in it, either as undergraduates or as graduate pre-professionals; until there is a greater number from which to recruit researchers, human biology, as the physical anthropologist understands it, will continue to be *terra quasi incognita*; and the less is known, the fewer will be the undergraduates to whom it will occur to spend time studying what is known.

Fifty-one of the 114 colleges answering the questionnaire offered physical anthropology as part of their curriculum; 26 of these taught physical anthropology as a separate course, and 25 taught the subject as part of another course, generally cultural anthropology. Twenty of the 51

schools had separate departments of "anthropology." The number of courses in physical anthropology taught in each school, and the approximate number of students enrolled in these courses, are tabulated.

### OBITUARIES

Because of his close association with the late Dr. Charles B. Davenport, Dr. Steg-

gerda was asked to prepare two obituaries, one for the journal of the American Association of Physical Anthropologists, of which Dr. Davenport was president at the time of his death, and one for Eugenical News. Each obituary contains a survey of Dr. Davenport's extensive work in anthropology, human heredity, and eugenics, and includes a complete bibliography of his writings in these fields.

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## NUTRITION LABORATORY

*Boston, Massachusetts*

THORNE M. CARPENTER, *Director*

The activities of the Nutrition Laboratory during the year have consisted, in the main, of investigations on war research projects that are carried on under a contract of the Office of Scientific Research and Development with Harvard University. These studies are conducted in cooperation with the Harvard School of Public Health. The investigation that was started on January 1, 1943 is still in progress. During the year two reports of parts of the research have been completed for the Office of Scientific Research and Development, and a third is nearly completed. Again emphasis can be laid on the usefulness of the Nutrition Laboratory's equipment, already on hand, in the experimental procedures necessary for the conduct of the observations, and on the scientific value of the physiological information regarding human subjects that is being amassed in these wartime researches.

The special investigation on the metabolism of diabetes mellitus, which has been carried on under a special grant from the

Carnegie Institution of Washington, with the active cooperation of Dr. Elliott P. Joslin and Dr. Howard F. Root, of the New England Deaconess Hospital, was terminated with the resignation of Miss Jeannette F. Rayner, on June 30, 1943. The results of the several phases of this investigation are being prepared for publication.

Dr. J. H. Mueller, of the Department of Bacteriology and Immunology of the Harvard Medical School, who has been carrying on a war project in two rooms of the Nutrition Laboratory since December 1942, vacated the rooms in December 1943, and the equipment has been removed.

A study of physiological and clinical interest has been made on the breathing pattern and the rate of air flow in asthmatic patients, by Dr. Leslie Silverman and Mr. Robert C. Lee in cooperation with Dr. Cecil K. Drinker, of the Harvard School of Public Health, and Dr. Francis M. Rackemann, of the Massachusetts General Hospital. The results are in process of publication.

### STAFF NOTES

Mrs. Mary F. Schroader, who was appointed laboratory technician on a part-time basis on March 11, 1943, terminated her services with the Nutrition Laboratory on March 31, 1944.

On September 10, 1943, and again on June 30, 1944, Dr. Carpenter gave his annual lecture on basal metabolism to students of the Harvard Medical School.

Throughout the year the full time of Robert C. Lee, George Lee, and V. Coropatchinsky and about half the time of Dr. Carpenter have been devoted to war research projects. About two months have been spent by Miss Elsie A. Wilson in the editing and final copying of reports to the Office of Scientific Research and Development.

### LITERARY WORK

The following articles have been completed for publication in scientific journals:

"A new method for studying breathing, with observations upon normal and ab-

normal subjects," by Leslie Silverman, Robert C. Lee, and Cecil K. Drinker. (Accepted for publication in the *Journal of Clinical Investigation*.)

"The effects of glucose, fructose, and galactose on the respiratory exchange of the goat," by Ernest G. Ritzman and Thorne M. Carpenter. (Accepted for publication in the *Journal of Nutrition*.)

"The effects of sugars on the respiratory exchange of cats," by Thorne M. Carpenter. (Accepted for publication in the *Journal of Nutrition*.)

Articles in process of preparation and nearing completion are:

"Effects of oral ingestion of glucose and

fructose on respiratory quotient, blood sugar, and pyruvate and lactate levels of the blood of diabetics," by Elmer Stott, Howard F. Root, and Thorne M. Carpenter.

"Effect of the level of the basal respiratory quotient on the respiratory quotient after ingestion of glucose by normal men," by Thorne M. Carpenter and Howard F. Root.

"Racial metabolism from the standpoint of anthropology."

Miss Elsie A. Wilson has participated actively and efficiently in the calculations and the editorial preparation of these manuscripts and of the publications listed below.

## PUBLICATIONS

(1) *Partial pressures of carbon dioxide and oxygen in expired air and alveolar air when oxygen is breathed at different atmospheric pressures.* Thorne M. Carpenter and Robert C. Lee. *Jour. Aviation Med.*, vol. 14, pp. 240-249 (1943).

Six normal men were studied at rest and at work, while breathing room air or oxygen at sea level and while breathing oxygen in a low-pressure chamber at different atmospheric pressures ranging from 523 to 163 mm. (corresponding to altitudes of from 10,000 to 37,000 feet). The subjects were sitting when at rest and rode a bicycle ergometer during work, with a performance of about 1300 foot-pounds per minute. Under resting conditions, the average differences in the partial pressures of carbon dioxide in expired and alveolar airs ranged from 13.0 mm. at sea level (breathing air) and at an atmospheric pressure of 350 mm. (breathing oxygen) to 10.5 mm. at an atmospheric pressure of 163 mm. The average differences in the partial pressures of oxygen in expired and alveolar airs ranged from 22 mm. at sea level (breathing oxygen) to 12 mm. at an atmospheric pressure of 163 mm., and the differences gradually became smaller with lowering atmospheric pressures. At work,

the average differences in the carbon dioxide pressures varied from 14.5 mm. at an atmospheric pressure of 523 mm. to 9.0 mm. at 230 mm., and the average differences in the two oxygen pressures ranged from 32 mm. at sea level (breathing oxygen) to 9 mm. at 163 mm. The sums of the alveolar partial pressures of carbon dioxide, oxygen, and water vapor at a pressure altitude of 37,000 feet agree well with the sums of the arterial partial pressures at 37,500 feet noted by another investigator.

(2) *Absorption of insulin labeled with radioactive iodine in human diabetes.* Howard F. Root, J. W. Irvine, Jr., Robley D. Evans, L. Reiner, and Thorne M. Carpenter. *Jour. Amer. Med. Assoc.*, vol. 124, pp. 84-90 (1944).

Doses of 25 units of radioactive insulin-4-iodoazobenzene ( $\frac{1}{3}$  to  $\frac{1}{2}$  unit per kilogram) were given subcutaneously to 10 diabetic patients and 5 normal individuals. The rate of absorption of the insulin was measured with a gamma ray counter immediately after injection and 20 minutes, 1 hour, 2, 4, and 8 hours thereafter. Supplementary insulin was given to the diabetic patients throughout the day, as needed, and 100 ml. of orange

juice each hour. The normal controls had no food during the tests. Insulin absorption took place at an almost equal rate in the normal subjects and the patients with uncomplicated diabetes. This rate was rapid in the first 2 hours but became progressively slower in the next 4 to 6 hours. A pronounced delay in insulin absorption was caused by areas of induration or of pad formation, but when such insulin pads had disappeared because insulin was no longer injected in the areas, the tissues regained the power to absorb insulin rapidly. A marked delay in absorption was also noted with insulin-resistant patients, but during recovery from such resistance the rate of absorption became normal. The rate of absorption was not affected by the initial level of blood sugar. The delay in absorption is not related to long duration of diabetes, but to the condition of the tissues at the site of injection, and tends to be corrected by continued use of insulin in doses large enough to control glycosuria and hyperglycemia. The amounts of radioactive substance found in the urine excreted during the 24 hours following the injection were, in general, lower in the resistant patients. The hypothesis is advanced that in cases of insulin resistance, which is associated with marked delay in absorption of insulin, the metabolic or structural changes in diabetic tissues take place under the influence of some factor such as a disturbance in hormonal and enzymal relations.

(3) *Human respiratory quotients in relation to alveolar carbon dioxide and blood lactic acid after ingestion of glucose, fructose, or galactose.* Harold T. Edwards, Edward H. Bensley, David B. Dill, and Thorne M. Carpenter. *Jour. Nutrition*, vol. 27, pp. 241-251 (1944).

The respiratory quotients (R.Q.), blood lactic acid, and alveolar carbon dioxide of two men were studied before and for 4 hours after ingestion of 50, 75, and 100 grams of glucose, fructose, and galactose. The alveolar carbon dioxide underwent little change in the glucose and the fructose experiments as compared with the no-dose experiments, but

decreased appreciably in the galactose experiments. The blood lactic acid increased after ingestion of all three sugars, the increase being greatest and lasting longest after fructose ingestion. The R.Q.'s were corrected for these changes, the calculations consisting in correction of the carbon dioxide elimination for the change in alveolar carbon dioxide and for the theoretical change produced in the carbon dioxide content of the blood by the rise or fall of the lactic acid content of the blood. The greatest corrections of this nature were those for the fructose experiments. The resultant net changes in R.Q. ascribable to ingestion of the sugars (calculated by comparison of the corrected quotients after sugar ingestion with the basal or preingestion levels) were much the same after ingestion of glucose and of galactose. After glucose was ingested, the maximum net increase took place within 90 to 135 minutes, and there was no return to the preingestion level in 4 hours. The greatest net increases, however, occurred after fructose ingestion. This implies that there is a more rapid combustion of carbohydrates after ingestion of fructose than after that of glucose or of galactose. Some of the R.Q.'s approached or equaled unity, particularly after ingestion of fructose and of galactose. These high R.Q.'s may result from conversion of sugar to fat as well as from increased combustion of carbohydrate. The order of possibility in respect to conversion to fat might be fructose, galactose, and glucose.

(4) *The effects of hexoses on the respiratory quotients of cats.* Thorne M. Carpenter. *Federation Proc.*, vol. 3, p. 93 (1944).

A preliminary communication of results to be published in full subsequently.

(5) *The effects of hexoses on the respiratory exchange of rhesus monkeys.* Thorne M. Carpenter and Carl F. Hartman. *Amer. Jour. Physiol.*, vol. 141, pp. 249-254 (1944).

The respiratory exchange of 7 adult female rhesus monkeys was studied for 4 hours after administration by stomach tube of 14 grams of glucose, fructose, or galactose, or of 105 ml. of water, and for comparative pur-

poses under postabsorptive conditions. The greatest rises in respiratory quotient (R.Q.) occurred after administration of glucose, the next greatest after that of fructose, and the smallest after that of galactose. The proportion of the total heat production supplied by carbohydrates was greatest after glucose was ingested. The proportions were somewhat smaller after ingestion of fructose and of galactose, but about equal to each other. With man the order in this respect and also in respect to the rise in R.Q. is fructose, galactose, and glucose. With 5 of the 7 mon-

keys all three sugars caused increases in heat production of from 12 to 13 per cent, as compared with the heat production in no-dose and water experiments. The specific dynamic action of the sugars (the relation between the fuel value of the sugar and the increase in heat production above the base line during the 4 hours of measurement) averaged 11.3 per cent for glucose, 9.5 per cent for fructose, and 9.0 per cent for galactose, values somewhat higher than those reported for man after ingestion of 50 to 100 grams of these sugars.

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## SPECIAL PROJECTS: BIOLOGICAL SCIENCES

PAUL S. CONGER, United States National Museum, Washington, District of Columbia.

*Investigation and preparation for publication of results of studies on Diatomaceae.*  
(For previous reports see Year Books Nos. 18 to 42.)

The diatom work for the year consisted mainly in a continuation of investigations already in progress, including bibliographic compilation of general information regarding diatoms, ecological studies of Chesapeake Bay diatoms, and a study of the diatoms collected on President Roosevelt's expedition in Central American waters a few years ago.

During two months of the summer of 1943, investigations were carried on at the Chesapeake Biological Laboratory, including studies on the liberation of marsh gas, on which a paper was completed. One of the more interesting results of this summer's work was the obtaining of a still higher proportion of nitrogen than had been obtained in any samples of the previous year. Nearly 40 per cent of one sample was composed of nitrogen, and such amounts suggest important phases of the process of transfer and accumulation of this gas. New apparatus designed for more efficient collection and quantitative estimation of liberation of the gases was effectively used.

Several samples of species of diatoms used in pigment studies at the laboratory of the Division of Plant Biology of the Carnegie Institution were identified. Some examinations were made of organisms giving trouble in the Washington water supply, and other routine requests for information were given attention. Assistance was afforded the armed forces in several requests for information and examination of materials.

In March 1944, arrangements were completed for transfer of the work on diatoms

from the Carnegie Institution to the Smithsonian Institution, in which latter institution the work had actually been located for many years. This concluded sponsorship by the Carnegie Institution of work on diatoms, and with this transfer the Carnegie Institution presented to the Smithsonian Institution all diatom collections and equipment which had been used in the work. Thereby was unified and established at the Smithsonian Institution, with the presentation to it of the "Albert Mann Diatom Collection," one of the fine diatom collections of this country. The investigations are being continued there essentially as before, and hence in the consummation of this arrangement the wishes of Dr. Albert Mann have been fulfilled for securing the permanent establishment of the collections and investigations started by him. That this field of work was advisedly sponsored by the Carnegie Institution from its inception in 1919 seems indicated by the increasing and significant demands for information concerning diatoms from students of oceanography and aquatic biology, and from industries utilizing diatomaceous earth and products. The benefits of the assured continuation of this work can therefore be estimated in both commercial and scientific values, the diatoms being small and unobtrusive organisms, but widespread, unique, and potent in effect.

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ARTHUR T. HERTIG and JOHN ROCK, Boston Lying-in Hospital, Boston, and Free Hospital for Women, Brookline, Massachusetts. *Research in embryology, embryological pathology, and reproductive physiology.* (For previous reports see Year Books Nos. 36 to 42.)

These studies on reproductive physiology and pathology have had continued support of the Carnegie Institution of Washington's Department of Embryology. As in the previous five years' work, the William F. Milton Fund of Harvard University has helped to support these studies by virtue of a grant to Dr. Rock for work on tubal and ovarian ova. Since the two authors collaborate in each of the studies, joint credit is given both sources of financial support.

Since the last report, one free and two recently implanted human ova have been discovered in uteri removed surgically at the Free Hospital for Women. Of this particular group of patients, 88 have been extensively studied during the past 6 years, and 17 fertilized ova have been recovered, an incidence of pregnancy of approximately 20 per cent. During the past year 16 such patients have been studied and from them were recovered the 3 ova mentioned above. It is quite probable that in subsequent studies, as in the past year, fewer fertilized ova will be found, since the patients are operated upon during the phase of the menstrual cycle when the ovum is either free or recently attached to the endometrium. These little-understood stages of human development, because of technical difficulties inherent in finding them, will be more difficult to procure, even though an ovum may be in the uterus or tubes being examined.

The free segmenting ovum (Carnegie no. 8190) was discovered in Locke's fluid, pipetted out of the endometrial cavity of a uterus removed on the 21st day of the menstrual cycle. Since the patient's previous cycles had varied from 25 to 32 days

in length, the 17th- to 18th-day endometrium encountered in the specimen is a more accurate index of the probable age of this specimen. In all probability the ovum was not over 4 days of age, since in the classic menstrual cycle ovulation occurs on the 14th and menstruation on the 28th day of the cycle. Thus the human ovum, at least in this one instance, reaches the uterine cavity within 4 days. This is at the beginning of the period when active uterine secretion is just starting—a fact of probable significance with respect to nourishment of the ovum during its preimplantation phase.

The ovum in question when seen in the unfixed state was refractile in appearance and oval in outline, and measured 0.19 × 0.15 mm. It had a thick zona pellucida which surrounded what appeared to be 4 large and 6 smaller blastomeres. The specimen has subsequently been serially sectioned by Dr. Chester H. Heuser in the Carnegie Institution of Washington's Department of Embryology.

There is some question as to whether this ovum is perfectly normal, since some of the blastomeres have more than one nucleus. At any rate, this specimen is the only free ovum thus far found in the human uterus, so that further specimens must be discovered to determine the characteristics of the normal ovum during this phase of its development.

The next youngest specimen (Carnegie no. 8225) discovered this past year is a 7½-day blastocyst recovered in a bicornuate uterus on the 22d day of the menstrual cycle. It is quite similar in its gross and microscopic appearance to Carnegie no. 8020 (see Year Books Nos. 41, 42). Thus

the finding of two normal  $7\frac{1}{2}$ -day human ova whose menstrual and coital histories agree makes more certain than would just one such specimen the essential features of this phase of human development.

The oldest specimen (Carnegie no. 8215) discovered during the period of this report is approximately 9 days and is intermediate in development between the 8-day specimen (Carnegie no. 8171) reported last year (Year Book No. 42) and the  $9\frac{1}{2}$ -day specimen (Carnegie no. 8004) reported two years ago (Year Book No. 41).

The 9-day specimen, aside from filling a gap in our knowledge of this phase of development, is valuable because it was recovered on the 56th day of the menstrual cycle. Ovulation must have occurred only 9 days previously, or on the 47th day of the cycle. This specimen adds evidence as to the time of human ovulation, namely, the 14th day  $\pm$  2 days preceding the next expected menstrual period. In the ordinary cycle of 28 days, ovulation therefore occurs on the 14th day, but in a patient with long or irregular cycles such as the one in question, ovulation may occur at any time with respect to the last period. Thus the preovulatory period of the cycle may be variable, but the postovulatory phase is relatively fixed, namely  $14 \pm 2$  days. The detailed evidence for these conclusions has been published in the past year.

The paper on the development of the trophoblast of the pre-villous human ovum has been completed and published in the past year. These studies utilized the ova discovered during the years 1938-1942 (see Year Books Nos. 38-41).

An account of the essential features of the two normal ova of approximately 8 days of age (Carnegie nos. 8155 and 8171) mentioned in Year Book No. 42 has appeared in abstract form in the *Anatomical Record*.

A detailed description of the  $7\frac{1}{2}$ -day ovum (Carnegie no. 8020) and the  $9\frac{1}{2}$ -day ovum (Carnegie no. 8004), first recorded in Year Book No. 41, prepared for publication during the past year, will appear in the next issue of the *Contributions to Embryology*. In the same volume will be a paper on two early villous ova (Carnegie nos. 7801 and 7802), first mentioned in Year Books Nos. 39 and 40. These two ova have been extensively studied by Dr. Chester H. Heuser in collaboration with the authors.

During the past two years the studies on the pathogenesis of spontaneous abortion have been completed, using a series of 1000 abortuses. The clinico-pathologic correlation in cases of hydatidiform mole has been brought to a conclusion with the procurement of 200 cases of this condition. A paper embodying these findings is to be read in June 1945 before the American Gynecological Society.

Dr. Rock has succeeded in fertilizing 4 ovarian eggs *in vitro*. Upon subsequent cultivation, cleavage took place. In 2 of the specimens development ceased in the two-cell stage, whereas in the other 2, three blastomeres were observed before growth ceased. Details of these experiments have been published in *Science*.

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T. H. MORGAN and ALFRED H. STURTEVANT, California Institute of Technology, Pasadena, California. *Maintenance of a Drosophila stock center, in connection with investigations on the constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15 to 42.)

The following results on *Drosophila melanogaster* are reported by A. H. Sturtevant. It has been known that heterozygous inversions decrease crossing over in their own chromosome arms, and that there is an associated increase in crossing over in other arms. There is one method of measuring the total frequency of no-exchange tetrads for one chromosome, viz., through the frequency of secondary nondisjunction of the X chromosomes in XXY females, since all such exceptions are complete non-crossovers, and since there is reason to suspect that most no-exchange tetrads do give rise to such exceptions in the presence of a Y. Accordingly, a systematic study has been begun, in which various types of XXY females have been made heterozygous for a variety of autosomal inversions. This study is incomplete, but it is already clear that heterozygosis for autosomal inversions does decrease the frequency of secondary nondisjunction of X; it seems probable, however, that the decrease is a function of the particular autosomal region involved, as well as of the amount of autosomal crossing over suppressed. This result is in agreement with previous studies of interchromosomal effects, that have been carried out by other techniques and have been recorded in previous reports.

An unexpected result is that heterozy-

gosis for autosomal inversions increases the amount of primary nondisjunction of the X chromosomes, in the absence of a Y. This result has been obtained in several different kinds of experiments, and is certainly a general one. Its significance is not yet understood, but it is clearly the cause of the often noted occurrence of unusually high frequencies of primary exceptions. Since the exceptional males and females occur in equal numbers, the result is due to true nondisjunction, and not to chromosome elimination. These studies are being continued. Experiments are also under way to see if heterozygous inversions in other chromosomes induce primary nondisjunction of the fourth chromosome. The results here are negative so far, with the exception that inversions in X do seem to increase primary nondisjunction when one of the fourth chromosomes carries *ey<sup>D</sup>*. This chromosome carries a duplication of unknown origin; the present result suggests that the duplication may have come from X.

*Drosophila melanogaster* has yielded fewer genes producing diploid intersexes than have some other species of the genus. One was recorded in last year's report, and a similar one has since been found. A recessive mutant gene in the left limb of chromosome 3 (lying between *h* and *in*) has the property of turning genetic fe-

males into males. The transformed individuals (perhaps best described as extreme intersexes) are phenotypically normal males, except that they are of the larger size characteristic of females, and have small testes (which are, however, of normal shape and color). These individuals are wholly sterile, even when XXY in constitution. Males homozygous for the gene are fully normal and fertile; super-females homozygous for it have not yet been obtained, but it is clear that they have the same very low viability that is characteristic of ordinary superfemales. Attempts to introduce the gene in homozygous form into triploid intersexes are still under way, but it is already probable that such "double intersex" individuals are sterile.

There is a marked difference between the phenotypic effects of the recessive gene for intersex in chromosome 3 and those of the previously reported recessive gene in chromosome 2 (L. V. Morgan, Year Book No. 42). The latter does not transform females into complete males, but into individuals showing characteristics of both sexes. They have lateral anal plates, as have males, but they have no sex combs. Some individuals have female-like abdomens, others have different combinations of conspicuous genitalia of both sexes, and some have male-like abdomens and in-turned genitalia. In size the XX intersexes are intermediate between females and males. Males homozygous for the intersex gene are normal and fertile and are of male size.

H. C. SHERMAN, Columbia University, New York, New York. *Research on influence of nutrition upon the chemical composition of the normal body.* (For previous reports on this and directly preceding researches, see Year Books Nos. 32 to 41.)

The experimental work of this research, interrupted by war conditions at about the point described in our last report (Year Book No. 41, pp. 245-246), was resumed February 1, 1944.

The earlier experiments of this research have shown that although adult nutritional status (as influenced by riboflavin) is apparently "plateaued" when the level of nutritional intake reaches or exceeds 3 micrograms of riboflavin per gram of air-dry food, or 0.8 milligram per 1000 calories of the diet, there was additional benefit to the young when the riboflavin content of the family dietary was threefold higher.

From both chemical and biological viewpoints it is of fundamental significance to establish whether or not there is even a small difference in riboflavin content of body tissue resulting from differences in intake level above that just described.

Analyses made at fixed intervals of time

from end of infancy to early middle age (30 to 180 days in the rat) show that riboflavin content of muscle, other things being equal, is higher at the earlier ages and decreases slowly but steadily throughout this age range.

Comparing analyses made at fixed ages, with riboflavin as the sole significant variable of the food, further experiments have confirmed the finding that increases of 100 to 233 per cent over the above-described riboflavin intake resulted in only statistically insignificant gains; and that decreases of 50 per cent resulted in a marked decrease of concentration of riboflavin in the liver, and a smaller but measurable decrease in muscle also.

Thus the net result of our several series of experiments with riboflavin as sole variable in the diet is to confirm the general picture of a riboflavin content of body tissue which varies with the intake when

intakes are low, then "plateaus" at a fully normal level, and thereafter remains essentially constant when intakes are raised to higher levels.

There is reason, however, as briefly mentioned in our last report, for experiments in which the intakes of protein and phosphate as well as of riboflavin are increased. This is because the chief known form in which riboflavin is held in the body is in chemical combination with protein and phosphate. Considerable numbers of such comparisons have now been made, with the following results: The effect of age upon the riboflavin content of tissue is confirmed; but no measurable differences in composition of muscle were found to result from the differences in intake in these experiments, namely, increases of one-fourth in each of the three factors, riboflavin, protein, and phosphate, above the levels of the already liberal diet. In the liver the same was true except at the earliest age tested, where the richest diet resulted in an increased amount of ribo-

flavin. This increase was small but statistically significant, and becomes more clearly apparent when computed as the total amount of liver riboflavin in the body.

For this reason and because the advantage in nutritional well-being enjoyed by the young from the families on diets of higher riboflavin content does not seem to be entirely explained by the small difference found in the liver, we are now extending this phase of the research into analyses of the entire carcass.

On this, and on the relation of nutritional intake to body content of vitamin A, we hope to report further findings.

The generous and efficient service of those who have collaborated in the work here reported, whether as research assistants or as volunteers, is gratefully acknowledged.

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## DIVISION OF HISTORICAL RESEARCH

*Cambridge, Massachusetts*

A. V. KIDDER, *Chairman*

Because several members of the staff are serving in the Army and Navy or are engaged in other activities connected with the war, and because those not so engaged have been occupied with the preparation of reports, little field work has been done in Middle America. The Division has therefore been unable to meet in full the terms of its contracts with the governments of Mexico, Guatemala, and Honduras, which call for the annual expenditure of stated sums. The authorities in those countries, however, in the fine spirit of cooperation they have shown in all dealings with the Institution, have agreed to waive all financial requirements for the period of the present emergency. In the meantime the limited amount of field work that it has been possible to carry on, together with results of laboratory and archive research and study of data accumulated in former years, has permitted clearer formulation of problems to be attacked when full-scale activity can be resumed.

It is with great regret that we record the death, on September 1, 1944, of Dr. Charles Oscar Paullin, long a member of the staff of Carnegie Institution. Dr. Paullin joined the Department of Historical Research, forerunner of the present Division, in 1910. He collaborated with Dr. F. L. Paxson in preparation of the *Guide to the materials*

*in London archives for the history of the United States since 1783*, published in 1914; and edited the final volume of Miss Frances G. Davenport's *European treaties bearing on the history of the United States and its dependencies*, published in 1937. His principal undertaking, and one of the major enterprises of the Department and later of the Division, was the preparation of his *Atlas of the historical geography of the United States*. It was first planned in 1904, preliminaries were begun in 1912, and in 1914 the work was placed in the care of Dr. Paullin, who, aided by many specialists, brought it to completion with its publication in October 1932. In April 1933, Dr. Paullin, as author, jointly with Dr. John K. Wright, as editor, received the Loubat prize of \$1000 for the *Atlas*. This prize is presented every five years for the "best work in the English language on the history, geography, ethnology, philology, or numismatics of North America." Upon completion of the *Atlas*, Dr. Paullin undertook an investigation of the careers of eminent Americans, basing his research upon the sketches in the *Dictionary of American biography*, supplemented by genealogical and other records in the Library of Congress and elsewhere. This work was finished at the time of Dr. Paullin's retirement in 1936 and is awaiting publication.

### ACTIVITIES, 1943-1944

During the period under review the several members of the staff and associates engaged in the war effort have continued their service. Major H. E. D. Pollock, of the Army Air Corps, has been

on duty in Italy since the invasion of that country. Mr. Gustav Strömsvik, of the Royal Norwegian Navy, after a year with the North Atlantic convoys, was transferred to an English base and took part

in the original landings on the coast of Normandy. Lieutenants (j. g.) G. W. Brainerd and E. W. Andrews have been serving in the Navy overseas, the former in India. Mr. Karl Ruppert, a volunteer in the American Field Service, drove an ambulance with the British forces throughout the recent campaign in Burma. He has now been transferred to the Italian front, where during the last war he served with the United States Army Medical Corps. Miss Eleanor W. Ritchie, secretary of the Division, is an ensign in the WAVES, on duty in Washington.

In civilian capacities, Mr. R. E. Smith, after nearly two years as assistant to the United States military attaché in Guatemala, returned to the Division in June 1944. Mr. E. M. Shook has been engaged in the production of quinine in Guatemala. As his work took him to all parts of the Pacific slope of the Guatemala highlands, a region of great archaeological importance but one very little known, he was able to locate a large number of new sites, as well as to observe and photograph many private collections of antiquities. Dr. A. M. Halpern has continued as instructor in Japanese at the University of Chicago, Dr. R. S. Chamberlain as senior cultural assistant in the United States Embassy in Guatemala. Mr. F. B. Richardson has been serving as legal attaché at the Embassy in Ecuador.

Dr. S. G. Morley spent part of the winter in Yucatan compiling a card file of the Maya hieroglyphs carved on stone. In company with Mr. J. E. S. Thompson, he later visited archaeological sites in Chiapas, Mexico, returning to Yucatan by way of the Pasión and Usumacinta rivers. A report on these journeys appears below. Mr. Thompson, before and after the Chiapas trip, was in Mexico City studying the rich collections in the Mexico National Museum and conferring with the very

active and able group of archaeologists headed by Dr. Alfonso Caso, of the Instituto Nacional de Antropología e Historia. The members of the Instituto have been most cordial and cooperative, sparing no pains to render visits of the Division staff to Mexico City pleasant and profitable. In particular, Professor I. Marquina, acting director of the Instituto during the service of Dr. Caso as rector of the University of Mexico; and Professor E. Noguera, director of the National Museum, have been unremittingly helpful.

In September 1943 the Chairman attended the third round-table conference sponsored by the Anthropological Society of Mexico. These conferences, the first of which was devoted to the relationship of the Tula and Teotihuacan cultures, the second to the mysterious La Venta or Olmec culture of the Gulf coast, have served not only for the exchange of information and the formulation of scientific problems, but also to promote close personal relations between the archaeologists of Mexico and the United States, many of the latter having attended each of the round tables. That of 1943 concerned the prehistoric relations between the cultures of Mexico and those of southwestern and southeastern United States. At its conclusion the Chairman, with Dr. Isabel T. Kelly and Dr. Emil Haury, visited museums and private collections in Morelia and Jalisco and conferred at her laboratory in Guadalajara with Dr. Kelly, who, under a joint grant from the American Philosophical Society and Carnegie Institution, is devoting the current year to preparation of reports upon her very important excavations and surveys in western Mexico.

In April and May 1944 the Chairman was in Central America, spending several weeks in Salvador studying collections in the National Museum and observing the excavation of Tazumal, which is being

carried on by Mr. S. H. Boggs for the government of that country; and, in Guatemala, studying collections and conferring with Messrs. R. E. Smith and E. M. Shook. At that time there was planned an exhibit of the very beautiful paintings by Sr. Antonio Tejeda F. of pottery found by Mr. Strömsvik at Copan. This was later held at the Instituto de Bellas Artes in Guatemala City, was largely attended, and received much favorable comment in the press. Such exhibits, of which several have been held in former years, serve to arouse local interest in the preservation of antiquities and to promote understanding of the aims and methods of the Institution's work in Middle America. Similar results have been achieved by Dr. Morley's frequent lectures in Mexico and Guatemala and by those of Mr. Strömsvik in Honduras.

During the year Dr. Sol Tax directed the food survey of Guatemala and, in cooperation with the Instituto de Antropologia e Historia, directed a cooperative ethnological project in Chiapas. He devoted a third of his time to teaching at the University of Chicago. A report on the food survey is appended.

Sr. Alfonso Villa R. taught, from March to November 1943, a course in ethnographic methods at the Escuela Nacional de Antropologia e Historia (Mexico City), while gathering together the materials obtained in the Tzeltal community of Oxchuc (Chiapas) the previous year. In December he returned to the same community for six months, accompanied for two months by four of his students in the Escuela. Upon his return to Mexico City in June 1944, he began to bring together all his data of the two seasons (and those of his students) into a monograph on Oxchuc. He also accepted an invitation to resume teaching

at the Escuela Nacional for four months of the year.

Advantage has been taken of the lull in field activities to make progress with the writing of reports and with their preparation for press by Mrs. W. H. Harrison, editor of the Division (see her report below). Dr. F. V. Scholes and Mr. R. L. Roys have worked on their joint monograph on the history of the Acalan-Tixchel area, Mr. A. L. Smith on that concerning the excavations at Uaxactun. Mr. J. E. S. Thompson's report on El Baul has been completed, and that of Miss A. O. Shepard on plumbate pottery is nearing that stage, as are those of Mr. E. H. Morris on his work on the early cultures of northeastern Arizona, and of the Chairman in collaboration with Mr. E. M. Shook and Dr. J. D. Jennings on Kaminaljuyu, Guatemala. Miss T. Proskouriakoff's album of restored drawings of Maya temples and groups of buildings is now in press. It is believed that, in addition to its value to Middle Americanists, this work will be of much interest to students of Old World archaeology and to architects. During the year Dr. Tax continued preparation of his Panajachel (Guatemala) materials. Publication of his monograph on the economy of the Indians, now completed, was held in abeyance, and his comprehensive volume on the mental culture, which is nearly finished, was laid aside, while he worked on a short introductory volume about the community as a whole. This book should be near completion by the end of 1944.

There follow more detailed reports.

#### RECONNAISSANCE IN MEXICO AND GUATEMALA

S. G. MORLEY, J. E. S. THOMPSON

Dr. and Mrs. Morley visited Copan in February 1944. During Dr. Morley's stay he made observations on all the forty-one

stelae known at that site for the purpose of comparing the coefficients of glyphs C and X of their respective Supplementary Series in an endeavor to ascertain the cause of their observed interdependability. A new stela (no. 28), discovered by Mr. Strömsvik, was studied. This is only a fragment but presents a very early style of glyphs. Unfortunately it gives no date. The most important discovery of the trip was the identification of a heretofore unreported Initial Series. This was found sculptured on the south jamb of the west doorway of Temple 11, and records the date 9.17.2.11.16 (A.D. 783).

Later in February Dr. and Mrs. Morley met Mr. and Mrs. Thompson at Tuxtla Gutierrez and together they visited sites in the highlands of Chiapas. At Chinkultic there was discovered a new Early Period stela (the tenth at this site) bearing the Initial Series date 9.9.15.?.? (A.D. 628). This monument is important in that it carries the sequence of dates back a century and a half beyond the earliest previously reported at Chinkultic.

The party then moved to Tonina. This, the largest known Maya site in the Chiapas highlands, is beautifully located on the north side of the Jata Valley, a range of low hills having been terraced and utilized for the erection of pyramids and temples clear to the summit, some 300 feet above the valley floor.

The most important epigraphic discovery was an Initial Series inscribed on the back of a crouching anthropomorphic figure of heroic size (Sculpture T. 10). This may record the date 9.3.0.0.0 (A.D. 495), which is sixty years earlier than any previously reported at Tonina. Two new Period Ending dates were also deciphered: 9.12.5.0.0 (A.D. 677) on Sculpture T. 17, and 9.15.0.0.0 ? (A.D. 731) on Sculpture T. 34.

Tonina was evidently a city of consider-

able importance. The style of its sculpture strongly suggests connections with the great cities of the Usumacinta Valley—Piedras Negras, Yaxchilan, and Palenque—on the one hand, and with Copan and Quirigua in the southeast on the other.

On his return to Guatemala City in mid-March, Dr. Morley went to Quirigua to compare the coefficients of glyphs C and X of the Supplementary Series on the monuments of that site. On March 28 he flew to Flores, capital of the Department of Peten, accompanied by Mr. Virgilio Viscovich, of the Chicle Development Company, whose services had kindly been loaned to the expedition by Mr. Cloyd Smith, manager of the company in Guatemala, without whose timely and powerful assistance the expedition could not have covered so much ground in Peten in so short a time. Mr. Smith, in addition to permitting Mr. Viscovich to accompany the expedition as transport manager, not only placed at its disposal a powerful outboard motor for river travel, but also provided Dr. Morley with letters of recommendation to the company's contractors throughout Peten.

The expedition continued on to La Libertad in the great central Peten savanna by automobile the same afternoon, and the following day, again by automobile, to Paso Subin on the Rio Subin, a small tributary of the Rio de la Pasion. Here the party embarked in a dugout canoe, temporarily equipped with an outboard motor, for the trip down the Rio Subin and Rio de la Pasion, and reached La Florida late the same night.

The next morning Dr. and Mrs. Morley visited the near-by ruins of La Amelia, 5 miles distant, first reported by Messrs. Pollack, Smith, and Shook of the Division's staff in the spring of 1940; and continued down the Rio de la Pasion, reaching the important site of Altar de Sacrificios, 3

miles above the mouth of the river, that evening.

Altar de Sacrificios is located on the point of land between the Rio de la Pasión and the Rio Salinas, which unite, 3 miles below, to form the Rio Usumacinta, the largest watercourse in Central America. This site in ancient times must have been of considerable importance because of its strategic location. Up river, six to ten days by canoe, would have brought the Maya to where they could reach Quirigua in two days' journey by mountain trails, and within three days' journey of Copán. Three days up the Rio de la Pasión and the Rio Subín, and another three on foot through the forests and savannas of central Petén, would have brought them to Tikal, the largest city of the Old Empire, and, a day beyond, to Uaxactún in northern central Petén. Six to ten days up the near-by Rio Salinas would have put them in the important centers of the Guatemala highlands; six to ten up the nearby Rio Lacantún, a tributary of the Rio Usumacinta, brought them to the various centers of the Chiapas highlands. Finally, it required but two to three days' journey down the Rio Usumacinta to reach Yaxchilán, Piedras Negras, and Palenque, the greatest art centers of the Maya. Literally, Altar de Sacrificios lay at the crossroads of the Old Empire.

Here Mrs. Morley discovered three new stelae and three new altars, the former numbered 15, 16, and 17. Two new Initial Series were found: 9.3.0.0.0 (A.D. 495) on Stela 13 and 9.10.?.?.? (between A.D. 633 and 652) on Stela 16; and two new Period Ending dates: 9.14.10.0.0 ? (A.D. 721) on Stela 2 and 9.15.0.0.0 ? (A.D. 731) on Stela 17. Most significant, however, was the correction of Dr. Morley's former readings of the Initial Series on Stelae 10 and 11 from 9.7.10.0.0 (A.D. 583) to 9.2.0.0.0 (A.D. 475). This extends the sequence of dated monu-

ments at Altar de Sacrificios backward some fifty years and, indeed, makes this site, on the basis of the dated remains, forty years earlier than any other known city in the Usumacinta Valley. It raises the implication, moreover, that Maya culture reached the Usumacinta Valley by way of the Rio de la Pasión and thence down the Pasión Valley, rather than via the Rio San Pedro Martir in northwestern Petén and thence up the Usumacinta Valley, as Dr. Morley formerly believed.

The expedition left Altar de Sacrificios for the return journey up the Rio de la Pasión on April 3, stopping at La Florida to visit the near-by ruins of El Caribe, discovered by Messrs. Pollock, Smith, and Shook in 1940, and the ruins of Aguas Calientes, discovered by Drs. Morley and Spinden in 1914. The next afternoon La Libertad was reached, and the following morning was spent at the ruins of Polol, some 8 miles west of La Libertad, first reported by C. L. Lundell, of the Institution's botanical expedition to Petén in 1933.

Dr. and Mrs. Morley flew from Flores to Paso Caballos on the Rio San Pedro Martir on April 11, where they were met by Mr. Salomon González, the Chicle Development Company's contractor at La Florida on the middle reaches of that river, a few miles east of the boundary between Mexico and Guatemala. In March 1943 Mr. Shook had reported an important new site with sculptured stone monuments on the south bank of the Rio San Pedro at La Florida, which was reached by motor-driven dugout canoe from Paso Caballos on the morning of April 12. The ruins are located immediately behind the present chicle and rubber camp. Four new stelae were discovered; one new Initial Series, 9.15.0.0.0 (A.D. 731) on Stela 9, and one new Period Ending date, 9.16.15.0.0 (A.D. 766) on Stela 7.

The party left La Florida late the fol-

lowing afternoon by canoe downstream. The Guatemala frontier guard at Progreso on the north bank of the San Pedro River was passed the same night, and late the following day the expedition reached the small settlement of El Tiradero, Tabasco, Mexico, at which point the newly opened railroad from Tenosique to Campeche, Mexico, crosses the San Pedro. The next morning Dr. and Mrs. Morley left El Tiradero by rail for Campeche, and reached the latter point the same evening and Merida the following day.

#### HIEROGLYPHIC RESEARCH

J. E. S. THOMPSON

The elucidation of the purely numerical part of Maya hieroglyphic writing has progressed so far that the possibilities of further success along those lines continually diminish. Recently Mr. Thompson has attacked the problem from a different angle, that of seeking parallels between the hieroglyphic texts and the chronological sections in the books of Chilam Balam. There is a certain danger in that approach because we are not certain exactly what language was spoken by the people who erected the stelae. One may assume, however, that the language was some lowland dialect, because the highland Maya did not erect stelae with hieroglyphic texts. Unfortunately there are no chronological passages in Tzeltal, Chol, or neighboring lowland dialects or languages, but these are fairly close to Yucatec, the language of the books of Chilam Balam.

A start has been made in deciphering the many affixes attached to the hieroglyphs. Mr. Thompson has identified the affix corresponding to the Yucatec preposition *ti*, "at, on, or from," and elements indicating backward and forward. He has also advanced evidence that the symbol

for counting was the figure of the mythical fish called *xoc*, because this and the Yucatec word *xoc*, "count," are homonyms. This is the first good evidence that the Maya used rebus writing. The results of these investigations were published early this year under the title *The fish as a Maya symbol for counting*. Since the publication of that paper Mr. Thompson has come upon other material confirming beyond reasonable doubt his identification of the fish symbol as the *xoc* fish.

A variant of the affix used as the preposition *ti* appears with fair frequency in Maya inscriptions. Its occurrence in Yucatecan texts before the coefficients of month signs indicates that it represents the word *tu*, a contraction of *ti* and *u*, "of," for in the books of Chilam Balam *tu* is written before the day coefficient, for example *ox Cauac tu hunte Pop*, "3 Cauac at first of Pop." Here glyphs and words are in complete accord.

Another example of rebus writing is supplied by the completion sign, which consists of a hand over a moon sign and which immediately precedes the period ended. Here the moon sign can have no lunar significance, but *u*, the Yucatec word for moon, also means "of." The combination almost certainly reads *u dz'ococ*, "the completion of," for this expression occurs frequently in the books of Chilam Balam in connection with Period Endings.

Sometimes the hand is shown in the act of scattering grain, with the *xoc* bracket "count" as prefix. In this form the glyph usually follows a record of time completed or precedes the day on which it was completed. It is not improbable that here we are dealing with a past participle. *Dz'ocaan* means "brought to completion," and *ocaan*, "sown." One may assume that there is partial duplication here, such as occurs in Aztec rebus writing. For instance, the Aztec glyph for the town of

Cuahuacan is composed of a tree, an eagle, and the place symbol, but the first two elements, *cuahitl* and *cuauhli*, "tree" and "eagle," duplicate each other, one being redundant except to confirm the reading of the other. The Maya glyph, then, would read *xoc dz'oc (oc)aan*, "the count brought to completion."

Confirmation of the translation of one prefix as "forward" is supplied by its further use as prefix to an element which enters into the combination Teeple translated as "new moon" or "same moon age." Actually, the glyph has a somewhat wider meaning, for it is used to indicate that the date to which it is attached has lunar significance. When the forward prefix is added, the whole indicates that it is the later of the two dates between which it lies which has a lunar significance. This form occurs only at Palenque, where it was particularly needed because of the involved order in which dates and distance numbers were often recorded. Another affix is placed below period glyphs only when they occur as distance numbers.

Among the present-day Maya of the Guatemala highlands who still retain the old Maya almanac of 260 days, sunset marks the start of the new day. For Yucatan we have no direct evidence as to when the day started, but certain passages in the books of Chilam Balam suggest that the division came at daybreak or sunrise. A study, involving mythological concepts, of all variants of the glyph for day in Maya texts leads to the conclusion that the glyphs record a count by sunrises. It is, of course, possible that the starting point had shifted from dawn to dusk before the Initial Series period, but that the old terms had survived in speech and writing just as September etc. have survived in our calendar, although they are no longer the seventh *et seq.* months.

The time may not be far distant when

Maya hieroglyphic texts will have to be translated first into Maya in order to conserve the full richness of their message.

#### CERAMIC TECHNOLOGY

ANNA O. SHEPARD

The interruption of archaeological field work has reduced the volume of routine analysis of paste required of the technological laboratory, and thus afforded time for the study of aspects of ceramics ordinarily considered outside the technological field. The desirability of fully correlating stylistic and technological data and of using technological analysis to aid in the solution of well defined archaeological problems has often been stressed but seldom found easy of accomplishment. One way of facilitating such correlations is for the technologist occasionally to undertake general ceramic investigations. The study of plumbate ware, described in the last annual report, led naturally to two broader studies, one of design symmetry, the other of pottery form; these have constituted the principal projects of the year.

The design study was initiated by an attempt to compare the symmetry of plumbate design with that of fine orange ware, which had been described by Dr. G. W. Brainerd. A series of experiments with symmetry showed that the usual concepts and accepted definitions are limited to those relating to finite designs; it is not ordinarily realized that infinite linear or one-dimensional designs involve higher types of symmetry and are of seven basic classes, instead of three as in the case of finite designs. A method of classification was therefore developed for linear or band designs, and its applicability, as well as the significance of the evidence obtained, was tested by analyzing a large series of designs from four Southwestern and three Middle American wares which are well

illustrated in the literature. The Southwestern design systems chosen for study were: that of Mesa Verde, representing rectilinear and cursive design of the Classic Pueblo period; that of Pecos Glaze Paint ware, for simple panel treatment in a medium which required progressive design simplification; that of Santa Domingo, for curvilinear design of the historic period; and that of classic Mimbres, chosen because of the complexity of its structure. The Middle American systems included, in addition to Plumbate and Fine Orange, that of Coclé, Panama pottery, which is characterized by specialization in scroll patterns. The contribution which symmetry makes toward the understanding of design relationships was compared with that of structure and design elements which are recognized criteria in design analysis. Results of the study have been summarized in an illustrated paper.

Form is of primary interest to the student of Mesoamerican pottery because of its diversity, and particularly because many forms appear to be peculiar to periods or regions. It seemed desirable at this stage to summarize our knowledge of pottery shape in order better to trace the distribution of specialized forms and to understand the influence of one region upon another as revealed by the sum total of form traits. A card index of pottery form has therefore been started to facilitate such a summary, and also to guide the systematization of form classification and definition, and to lead to broad comparative studies of the pottery shapes of different culture areas. To date, over a thousand cards have been prepared, and a consistent working classification has been devised. The task of checking reports for this material has incidentally constituted a suggestive review of ceramic literature.

In the fall, six weeks spent in the East were devoted in part to library work in the

Peabody Museum at Cambridge and in part to the study of museum collections. Details of costume shown in codices, sculpture, and pottery were reviewed for comparison with representations on plumbate effigy vessels. The study of museum collections followed a series of experiments with incised decoration planned to ascertain whether or not the use of different tools such as the gouge, knife, and point could be recognized. The effects of paste hardness and texture on the quality of linework were also investigated, and an instrument for measuring the depth of incised lines was devised.

Petrographic analysis during the year was limited, first, to a revision of the technological notes for the Kaminalijuyu report, together with further study of volcanic ash temper with relation to the question of the extent to which ash from different sources can be recognized; and, second, to the analysis of stucco and pigment samples from fresco-decorated wares of Guatemala, Mexico, and Salvador. In the stucco samples, a variety of materials and techniques was recognized which should aid in identifying the work of particular schools of stucco decoration.

In anticipation of the preparation of a handbook on methods of pottery analysis, a bibliography has been prepared which covers current periodical literature on recent ceramic research and analytical method of interest to the technologist. In the same connection recent literature on color standards and color nomenclature has been reviewed.

#### SOUTHWESTERN ARCHAEOLOGY

E. H. MORRIS

During the past year Mr. Morris made progress on his report on the early Basket Maker sites near Durango, Colorado, which have been described in previous

issues of the Year Book. The completion of this report has been much deferred by the loss of assistants and secretaries to the war effort.

A study of Anasazi cross-woven sandals, started as a side venture to utilize the skill of an unusually able artist-draftsman, Miss Jean G. Zeigler, has developed into a major undertaking. The study was begun upon a series of 300 sandals recovered during excavations by the Institution in 1931 among cave sites in northeastern Arizona. Examination soon emphasized what has been known in a general way before, namely, that because of intricacies of weave and profusion of decoration, their cross-woven sandals represent the highest accomplishment of the Anasazi in both manipulative techniques and artistic expression.

The Carnegie collection consists almost wholly of specimens of Basket Maker III age—roughly from A.D. 500 to 700. Although a report upon these alone would mount to monographic proportions, it would characterize but a relatively brief stage in the life history of an art that was practiced long before and after. Hence it was decided to broaden the study by recourse to specimens borrowed from other collections, to cover the entire time span through which cross-woven sandals are known to have been manufactured.

For purposes of generalization, the ranking type of cross-woven sandal is a flat sole of extremely tight and hard fabric, made from cordage, coarse to fine in different specimens. The cords most frequently are of yucca fiber; the warps are always so, but for weft, other materials such as Indian hemp, human hair, and, late in the cycle, cotton sometimes were employed. In early specimens the warps run longitudinally and the toe ends grade from square to deeply scalloped. Eventually the scalloped toe was changed to one

fully rounded by laying out the warps in U shape, with open end at the heel. Customarily the upper surface is free of structural pattern, but presents transverse bands of different texture, dependent upon whether in a specific area the wefts were twined or woven in plain over-under technique. On this upper surface appear the designs accomplished by the use of dyed wefts—yellow, several shades of red, brown, and black. The designs, of necessity geometric, are of great variety, often of extreme complexity, and invariably pleasing to the eye.

In intricacy and difficulty of accomplishment, structural embellishment of the nether surface of the sandals outdoes the colored patterning of the side that went next the foot. Such ornamentation could be achieved only in finger-woven fabrics constructed without the use of the loom or other mechanical aid. Evidently the art had been long practiced before the time from which the oldest known examples have survived, since many of the oldest specimens exhibit the greatest complexity of weave. This consists in the production of structural pattern by the introduction on the under side of supplementary warps and wefts, which were variously wrapped and twisted about one another to accomplish the ornamental effect. The result is a two-ply fabric held together only by occasional looping of the secondary around the primary warps. Eventually the use of secondary warps and wefts was given up, probably because it was found that comparable raised decoration could be produced by devious wrappings and knottings of the weft cords themselves.

The earliest dated site which has yielded cross-woven sandals is du Pont Cave in southern Utah, A.D. 217. The latest is the Aztec Ruin in northern New Mexico, which was built between A.D. 1110 and 1121 and was occupied for some time

thereafter. Thus the life span of cross-woven sandals was in round numbers fully 1000 years. Why the Anasazi saw fit to expend the best of their mechanical ability and their full craving for beauty on foot-gear that would but little outwear the time it took to produce it, we shall never know. But in so doing they left the richest heritage of early North American art, as expressed in perishable media, that has survived to the present. It is the intention of Mr. Morris to continue his current study until the range and sequence of techniques employed and decorative effects achieved in cross-woven sandals can be presented for publication in adequate detail.

#### SOCIAL ANTHROPOLOGY

ROBERT REDFIELD, SOL TAX, AND ASSOCIATES

Because of duties connected with the war activities of the University of Chicago, Dr. Redfield was unable to take the field. He remained, however, in close touch with the ethnological work of the Division.

The principal undertaking of the period under review was a survey of the food consumption and food habits of the nonurban people of Guatemala. The project is designed to complement a similar study carried out some years ago by the Division in cooperation with the Nutrition Laboratory among Maya living under very different conditions, both of climate and of soil, in northern Yucatan.

By far the most important of the manifold practical problems of human existence is that of filling the stomach. Men must be fed before any other activity can be undertaken. The quality and quantity of their food determines their health and vigor; the ease or difficulty of its attainment regulates the amount of effort they may put into activities beyond and above the mere business of keeping alive. Food supply and physical environment interlock

to produce the most cogent conditioning factors of any people's career. No anthropological or historical investigation can therefore strike very deep without taking them both seriously into account.

From the archaeological point of view, studies of food and cooking among the living Indians of Middle America are necessary in order to give us information regarding food and its preparation in former times. This is needed to make clear the uses of utensils found in excavation. Of greater importance is knowledge of the nature and amount of food required by the ancients, in order to permit estimates of the number of people who could have been supported in various sorts of country. That modern data will be, so to speak, retroactively reliable is indicated by the strong conservatism of the Maya in other regards, as, for example, in clothing, in agricultural practices, and in house building. And for present-day needs the survey will furnish basic data on the food of the country as a whole for comparison with that of other countries and regions and for determining the nutritional factors in problems of public health in Guatemala; as well as for comparisons of foods consumed in different types of Guatemalan communities in order to weigh the geographic, agronomic, economic, and cultural factors involved in such differences. Plans for the survey were drawn in August 1943 following a conference in Guatemala City between Dr. Tax and Srs. Goubaud and Rosales, and field work was begun the next month by Srs. Goubaud and Rosales and Sr. Agustin Pop, a young Guatemalan who has been Sr. Rosales' assistant in San Pedro la Laguna.

Since the attempt is to determine the kinds and quantities of food consumed, with little or no immediate reference to causes and effects, or to the chemical composition of the foodstuffs, the data that

are being collected are limited to detailed records of the daily consumption of individuals of sample families, to recipes (to make the consumption records exact and intelligible), to information on kitchens and utensils and customs relating to food, and to a general index of foodstuffs used throughout the year, with information on prices, seasonal variations, etc.

Considerable attention is paid to obtaining a scientific sampling of families for study within each community. The importance of getting an adequate cross section made it advisable to choose, so far as possible, communities in which ethnological studies have already been made, so that the economic and social distinctions that must be taken into account can be known without further extensive work. In regions where no such investigations have been undertaken, more time was allotted for the survey. Otherwise, the communities were chosen to represent regional, geographical, cultural, and social differences in the country as a whole.

By the end of June, Sr. Goubaud had completed work in five communities: those of Ladinos and Indians in San Luis Jilotepeque (Pokoman) and Jocotan (Chorti) in eastern Guatemala, and in the coffee plantation "Nueva Granada" in the southwest extremity of the country, where the Indians are largely of Mam origin. Simultaneously, Srs. Rosales and Pop completed studies in another five communities, all in Central Guatemala: the highland Indian towns of San Pedro la Laguna (Zutugil) and Panajachel (Cakchiquel), the Ladino communities of Solola and Agua Escondida, and the lowland colony of San Pedro Indians in the village of Cutzan. By the end of 1944 Sr. Goubaud is scheduled to finish work on the Indians of San Miguel Chicaj (the easternmost Quiche town, in Baja Verapaz) and on the Indians and Ladinos of San Juan

Chamelo (a Kekchi town of Alta Verapaz). In the same period Srs. Rosales and Pop will study in Aguacatan (southeastern Huehuetenango), where there appear to be two possibly distinct Indian groups as well as a settlement of Ladinos, and in the Mam Indian town of Santiago Chimaltenango (western Huehuetenango); if they have time, they will also collect food data in Santa Eulalia, a Chuj town in northern Huehuetenango.

Field studies will be finished by the end of 1944, and during the first months of 1945, Sr. Goubaud will compile and correlate the data and draw conclusions. Sr. Rosales, meanwhile, can return to his report on the culture of San Pedro, work on which was suspended to permit his participation in the food survey.

Partly to choose communities to be studied in the food survey, partly to obtain first-hand knowledge of northern Guatemala, a month's reconnaissance of Huehuetenango, northern Quiche, and Verapaz was undertaken in April. Dr. Tax entered Guatemala from Chiapas at the extreme northwest corner of Huehuetenango, where Srs. Goubaud and Rosales met him. Together, by horseback and automobile, they then traveled across the whole of northern Guatemala almost to the Lago de Izabal, stopping on the way in about forty communities. Besides obtaining a general idea of the geography and sociology of the area, for comparison with that to the south, they were able to trace the changing religious complexes and other cultural differences by fixing attention upon a small number of specific cultural traits.

Work in Chiapas made great strides during the year. It has been mentioned that Sr. Villa completed a second season in Oxchuc, this time accompanied by four students. In addition, three of the students who last year were trained in Zinacantan

by Dr. Tax returned to Chiapas in December 1943 for six months' field work in the region. Sra. Calixta Guiteras Holmes, whose special interest was the family and clan organization, worked especially in San Pedro Chenalho (Tzotzil) and in Cancuc (Tzeltal); Sr. Ricardo Pozas Arciniegas, specializing on the economy, studied chiefly in Chamula (Tzotzil) and Huistan (Tzeltal); and Sr. Fernando Camara Barbachano worked in Tenejapa (Tzeltal) and San Miguel Mitontic (Tzotzil), especially on the politico-religious organization. Funds for their work were supplied equally by the Instituto Nacional de Antropologia e Historia (Mexico), the state of Chiapas, and the University of Chicago, but the project was consummated under the direction of Dr. Tax, with advice from Dr. Redfield and Sr. Villa. Sr. Villa had numerous contacts with the three field workers. Dr. Tax directed the work by correspondence, and before making the reconnaissance of Guatemala, in April, he spent a week in Chiapas in consultation with Sra. Guiteras and Srs. Pozas and Camara.

As a result, comparatively full information about the whole highland Tzeltal-Tzotzil region of Chiapas is now at hand; during the next year the field notes will probably be organized and one can expect that for the first time real understanding of the ethnology, sociology, and economy of this hitherto unknown region will emerge. Indeed, within the space of two years we have probably obtained as much information about this area as there is available about any similar area in all of Middle America. The region appears to be of extraordinary importance ethnologically, with a social organization of a type more primitive than any hitherto encountered in Middle America.

To facilitate the elaboration of all the materials collected in Guatemala and

Chiapas during the past ten years, both by members of the Institution staff and by others, a project to microfilm manuscript material, which can then serve as a basis for specialized publications, has been inaugurated. It is hoped to gain the co-operation of institutions and individuals that possess unpublished materials on Middle American ethnology, social anthropology, and linguistics, in order to obtain a complete library of microfilmed materials that can be used by all concerned. Plans already under way include the microfilming of a large body of manuscript materials; Mr. Melvin Tumin is assisting with the editorial work. The more difficult problem is that of obtaining means to index all the materials to make them easily usable by scholars in the field. If the project comes to fruition, it will solve the dilemma posed by the practical impossibility of publishing all field data collected, on the one hand, and on the other the undesirability of publishing conclusions and interpretations without making available the material on which they are based.

#### HISTORY OF THE MAYA AREA

F. V. SCHOLES, R. L. ROYS, E. B. ADAMS

During the past year Mr. Scholes and Mr. Roys have devoted a large part of their time to the volume on Acalan-Tixchel. Mr. Roys was also occupied with details of proofreading and indexing his recently issued work entitled *The Indian background of colonial Yucatan*.

In the course of the year various series of documents relating to the colonial history of Yucatan have been extracted in preparation for other studies in progress. Two groups of these papers deserve notice at this time.

Of special interest to the historian and the ethnologist is the *probanza* of services

of Padre Antonio de Arroyo, a native of Yucatan, who served for seven years (*ca.* 1586-1593) as *cura* and vicar of Chancenote, and later (*ca.* 1593-1596) in a similar capacity at Peto. From 1597 to 1603 he officiated as a *cura* in the cathedral of Merida, and in 1598 was appointed visitor general for ecclesiastical affairs in Tabasco by the bishop, Fray Juan Izquierdo. In 1603 he also had charge of the parishes of Santiago and Santa Ana in Merida.<sup>1</sup>

In 1592, while serving at Chancenote, Arroyo was authorized by the episcopal authorities (Bishop Izquierdo and his vicar general, Br. Pablo de Leon) to make an investigation of idolatry in the pueblos of the Chancenote area, where it was reported that many Christian Indians still practiced the "rites, ceremonies, and sacrifices of idolatry as in ancient times." He was instructed to find out who these Indians were and the number of idols they possessed, and he was particularly charged to discover who served as *ah kins*, or native priests, "and the artisans who make the idols . . . and the [persons] who serve as *chaques* [*chacs*]." If possible, he was also to learn where the Indians kept their "books of idolatry" and where the idolatrous ceremonies were held. It should be noted, however, that his instructions expressly stated that he should proceed "with piety and mercy," imposing no pecuniary penalties and assuring guilty parties that if they would be good Christians in future a just and mild penance would be granted. In the case of the native priests and the artisans who made the idols, the bishop reserved to himself the right to pronounce sentence.

The probanza indicates that numerous *procesos* were formulated as the result

of these orders, and there is evidence that many of them were still on file, probably in the episcopal archive, a decade later. Unfortunately copies of these *procesos* were not incorporated in the probanza proceedings, and we assume that they are now lost. But the probanza records certain details which illustrate Arroyo's activities and the prevalence of idolatry in certain towns of the Chancenote district.

In Nabalam, where an investigation was made with the aid of Don Marcos Copul, cacique and natural lord of the pueblo, a considerable number of "hechiceros, sortilegos y idólatras" were punished. In the pueblo of Tixholop the cacique, Juan Tzama, was found guilty of idolatry, and we are told that the village of Tixmucul was "almost lost" because of the widespread practice of native religion there. Two native priests of Tixmucul are mentioned by name (Pedro Cocom and Juan Hun), and the testimony also states that Arroyo went in person to the milpas of the town, where he removed many clay idols, "which [the Indians] worshiped as gods."

In 1595 Arroyo made a similar investigation in the pueblos of the Peto district. Again we have references to the large number of *procesos* that were formulated and sent to Merida, but, as in the case of the proceedings at Nabalam, Tixholop, and Tixmucul, the actual documents are missing. It would appear, however, that in the Peto area idolatry was even more widespread than in the northeast.

Don Melchor Xiu, governor and cacique of Calamud (Calotmul), who later gave testimony as a witness for Arroyo, stated that in his own pueblo "almost all the citizens [*vecinos*] were public and secret idolaters." Here the priest punished many "hechiceros," both men and women, and removed more than six hundred idols. The probanza also tells about a certain

<sup>1</sup> The probanza is in Archivo General de Indias, Mexico, legajo 294.

Juan Puc, "a bishop . . . who, as chief of the said idolatry, was respected and obeyed." This "bishop" made use of a miter, described as being made of a *manta* painted yellow, a cope (*capa*), hyssop, "and other trappings of a pontiff and bishop," and he also had certain "books of idolatry." He was assisted by four other native priests, Juan Huh, Juan Na, Diego Chan, and Juan Mo, "who in the ministry of idolatry had divided the said pueblo of Calamud into barrios [*parcialidades*] and confradías." From all these leaders Arroyo took away numerous "idols, trappings, and offerings of copal incense, *cuzcas*, *piedras*, cacao, and clothing which had been offered to the idols."

Don Antonio Pot, cacique and governor of Dzitmop, and Don Gaspar Chan, cacique and governor of Chunhuhub, were also guilty of idolatry and were publicly punished, along with many other Indians of their towns. Many other natives confessed in secret and handed over their idols.

It is evident that although a large number of Indians in the Chancenote and Peto areas were publicly chastised, the punishments were not severe. The bishop's instructions, as noted above, forbade the use of stern measures, and the testimony recorded in the probanza tells how Arroyo, by persuasion and mildness, induced the Indians to abandon their idolatrous practices. This is in sharp contrast with the record of Landa's investigation of 1562. It is true, of course, that we have no evidence of human sacrifice in these later documents, so that there was not the same need for drastic measures. Nevertheless, it seems clear that the bishop and his agent, Arroyo, consciously adopted a policy of persuasion and mild punishments, and this may indicate a new tactic in dealing with Indians who had reverted to their old religion and ceremonial practices.

The actual processes in these idolatry cases of 1592 and 1595 undoubtedly recorded a considerable amount of data concerning Maya religion and the manner in which it was carried on in post-conquest times, but the documents are apparently irretrievably lost. Above all, it is unfortunate that the "books of idolatry written in figures and characters" that were taken from the Indians and were still preserved in Merida in 1603 are now missing.

During the year Miss Adams has been making a study of numerous documents relating to French corsairs in the Yucatan area. The activities of these corsairs on the coasts of Yucatan and Campeche during the sixteenth century form an integral part of the whole history of the operations of French and English privateers and pirates in the Caribbean in that period. Although the commercial importance of this province and its principal port, San Francisco de Campeche, was comparatively small, their location, in close proximity to Cuba, Florida, and the New Spain port of San Juan de Ulua, made the possibility of any serious foreign encroachments there a potentially great danger to Spanish supremacy in the whole region. Moreover, the New Spain fleet passed close to these coasts, and if the Mainland fleet was to touch at Havana, it also had to pass near the Yucatan peninsula. The presence of corsairs along the Yucatecan shore was also a menace to all local coastal trade from New Spain to the Rio de la Hacha, and to the trade carried on with the islands.

Although French adventurers, especially Norman sailors, were the first to challenge Castilian monopoly in the Caribbean, the story of the most important period of their piratical activities, which began in the 1530's and continued into the 1590's, has been told only in part. During his researches in the Archive of the Indies

at Seville and the Archivo General de la Nacion in Mexico City, Dr. Scholes photographed a number of documents dealing with French attacks on Yucatan and Campeche which contain a large amount of new material concerning French depredations there and also supply hitherto unknown details illustrating the cooperation between French and English corsairs in their voyages to the Guinea coast and thence to the Spanish Main, during which they engaged both in illicit trade and in outright piracy. The most extensive of these documents make an interesting addition to the known accounts of Francis Drake's voyage to the Indies of 1571, when he apparently joined with the French for a time in harassing the Spaniards at the Chagre River. These papers, which consist of the trials by the Tribunal of the Holy Office in Mexico City of a number of French corsairs captured at Cozumel in 1571, supplement the accounts given in Miss I. A. Wright's *Documents concerning English voyages to the Spanish Main, 1569-1580* (The Hakluyt Society, Second Series, No. LXXI, London, 1932) of the operations of the English and French on the coast of Tierra Firme in that year.

The first time the French appeared in Yucatan was in the port of Campeche in 1559 after attacks on Santa Marta, Cartagena, and Puerto de Caballos. Although the details are not clear, it seems that they were driven back to Yucatan by a storm and voluntarily gave themselves up, stating that they had received news of the peace between France and Spain. Some of them were sent to the viceroy in Mexico City, and we do not know what was done about this group. The chief account we have of this incident is in the Inquisition trial of twelve who remained in Yucatan. The Tribunal in Mexico City had not then been created, and proceedings were instituted by Fray Francisco Navarro,

guardian of the Merida convent and commissary general of Yucatan, as ecclesiastical judge ordinary in accordance with the papal bulls which allowed the Franciscan prelates to exercise such jurisdiction where there was no bishop. As in all such instances, the main interest of the ecclesiastical authorities was in the heretical beliefs of the culprits, and their crimes of robbery and arson were investigated merely as proof of their pernicious lack of orthodoxy. Because of this attitude, the records of this trial and of those of other Frenchmen tried in later years before the Tribunal in Mexico City are tantalizingly difficult to use for our purposes. No attempt was made to compile a complete account of their piracies. The examinations of culprits and witnesses were all based on the desire to find out whether the accused belonged to the followers of Martin Luther (to the Spaniard of that time the term "Lutheran" included all Protestants), whether they had shown in word or deed any disrespect for the teachings of the Holy Mother Church, and whether they had committed sacrileges.

In Yucatan in the early months of 1560 fear and hatred of the foreign heretics had not yet reached the heights to which they were to mount within a very short time. Local citizens were appointed to defend the Frenchmen and seem to have taken fairly seriously their obligation to present a good case for their charges, aided in this by prudent professions of penitence for their errors on the part of the accused. The sentence imposed public penance, varying according to the degree of guilt, and only one man was condemned to corporal punishment. In addition to public penance, he was sentenced to 100 lashes and one year of service in the Merida cathedral. Whether any of these men were able eventually to return to France is a question. The names of some appear on a list in the

Cathedral of Mexico City, where they are described as heretical pirates reconciled in the year 1560.

In August 1561 the Spaniards were greatly alarmed by an attack on Campeche by three ships from Dieppe. The inhabitants of the villa fled to the bush, and some of the French went ashore, took everything of value they could lay their hands on, set fire to the town, and carried off five women. About fifteen citizens and an equal number of soldiers from Florida, who had arrived opportunely the day before, went out in pursuit of the French and were able to kill some and take five prisoners. The rest fled to their ships in a small boat, leaving their booty behind. The prisoners were hanged without delay, and warnings were despatched to Veracruz.

Although no other major incidents occurred on the coasts of the peninsula until 1571, from 1561 on the Spanish residents were greatly concerned about the danger from such attacks. Throughout the rest of the century representations were made to the Crown at frequent intervals, urging the need of fortifying the more vulnerable points, especially the villa of Campeche, and of providing arms and munitions for defense. It was not until the early seventeenth century, however, that the fortifications at Campeche were begun, although various defense measures of lesser importance were adopted from time to time. Such information as we have for the period 1562-1570 comes from widely scattered sources; these accounts are usually brief and unsatisfactory and often give no dates or exact detail.

In 1571, however, the citizens of Yucatan again had the satisfaction of capturing some of the Norman heretics who had kept them so uneasy about their vulnerable coast line. French corsairs appeared at Cozumel during Holy Week and seized a

vessel which was on its way to Honduras with a cargo of *mantas*, wax, and honey. A few days later some of the French landed at Sisal and went inland as far as Hunacama. A force sent from Merida when the alarm was given was too late to overtake them, and shortly thereafter Governor Cespedes sent three boats to search for them. During the following weeks the corsairs were reported from various places, and in late May they turned up at Conil, where they seized a vessel from Trujillo, Honduras, with a cargo of wine, oil, and other merchandise. Some days later about twenty of the pirates were surprised at Ecab by a force sent out from Valladolid. The French ships sailed away, and the men who had been left behind fled along the coast to Pole. Meanwhile a second force was sent from Merida to aid the one from Valladolid, but by the time they reached Pole the Frenchmen had crossed to Cozumel, where the Spaniards finally overpowered them. Nine or ten were killed in the battle, and ten were taken prisoner. Four of the latter were tried and hanged in Merida by the civil authorities, but we have no record of the proceedings. The other six remained in Yucatan until they were sent to Mexico City in 1572 to the newly established Tribunal of the Holy Office. The mass of confusing testimony in the cases against these men touches on their exploits from the time they sailed from Honfleur until they were deserted by their companions at Ecab. Their confessions show that all were natives of Normandy and that some had taken part in the Civil Wars in France on the Huguenot side. So much prejudice and vengeful feeling enters into the testimony against them, and their own admissions are so colored by their efforts to make a favorable enough impression upon the Inquisitor to save their skins if nothing more, that it is difficult to determine just

what can be relied upon as fact. The study of these papers is still in its preliminary stages, but after comparing them with the documents published by Miss Wright and her valuable introduction to them, it is already clear that these Frenchmen belonged to the same group who were harassing the coast of Tierra Firme independently and with Drake in 1571, for many names and events correspond.

French corsairs continued to turn up in the vicinity of Yucatan until the early 1590's, for besides preying on local shipping, they found the stretches of sparsely inhabited coast useful when it was necessary for them to put in for repairs or to obtain food supplies from the Indians. Most of the information we have about their activities after 1571 is of the same sketchy and unsatisfactory nature as that for 1562-1570, but there is no doubt that the necessity for being constantly on the alert against them was a continual problem for the residents of Yucatan. By the end of the century the French incursions in the Yucatan area had practically ceased, and the great period of the English and Dutch buccaneers was dawning.

In addition to his study of the pre-Spanish history of the Acalan, Mr. Roys has investigated the implications of this material for the history of northern Yucatan and Tabasco. The Acalan ruling class was a mobile group, presumably from Tabasco originally, and the bearers of a more or less modified Mexican culture. During the course of the narrative that has come down to us, they moved first from northeastern Yucatan to the Usumacinta River, and finally to the Candelaria basin in southwestern Campeche, where they carried on an extensive commerce reaching from the Gulf of Mexico to the Caribbean Sea.

On the basis of the native historical legends, the observations of the first Span-

iards, and the results of modern archaeological investigations, a tentative effort has been made to trace the effects of an intrusive Mexican culture in the northeast and along the Caribbean coast of the Yucatan peninsula, as well as in Tabasco.

Though the influence of this culture is evident in all three regions, it appears to have been strongest in Tabasco, where, even within the Chontal area, a number of Nahuatl-speaking towns existed. In Acalan it lessened somewhat; and in northern Yucatan, although its effects are evident, it appears in a much more attenuated form, particularly during the period immediately preceding the Spanish conquest.

Acalan was closely associated with Tabasco, where the same Chontal language was predominant. Comparatively little information has come down to us concerning the latter area until very recently, but with the aid of a number of early Spanish documents brought to light by Dr. Scholes, it has been possible to draw a more intelligible picture of this rich and important country, as it was at the time of the Spanish conquest. In addition to our previous general knowledge of the visits of merchants from Mexico, we are informed of their warehouses in certain Chontal towns and of the retail distribution of goods from these depots to the consumer. More detailed information is now available concerning the activities of the Tabasco traders, who ranged from southern Veracruz to the Ulua River in Honduras, and of the Yucatecan Maya towns in various parts of the peninsula, whose merchants had also established factories in the latter area. The historical importance of Tabasco has become increasingly apparent with the growing belief among archaeologists that the Mexican invaders who so strongly influenced a

great part of the Maya area passed largely by way of this region.

It has long been known that nearly all the Chontal-speaking towns in Tabasco have been designated only by Mexican names ever since the conquest; but it is surprising that the documents give only Nahuatl personal names for the inhabitants of these towns. In the case of converts this often became a surname and was preceded by a Christian name. In the Acalan records, however, the place names are all Chontal, but the personal names are a mixture of Chontal and Mexican, the latter often in a corrupted form. Some of these cast new light on a number of Yucatecan Maya names of doubtful origin. A tentative analysis of an early Tixchel list of tributaries will be presented as an appendix to the forthcoming volume on Acalan-Tixchel.

As yet this list is the earliest extensive compilation of native names from the lowland Maya area that has come down to us. The ethnological and sociological implications have been studied, and it offers certain puzzling features. Chief among these is the apparent evidence of a much stronger tendency toward matrilocal residence than we should expect in this region. Some possible explanations have been suggested, but these are not conclusive, and the attempt has been principally to formulate the problem involved.

#### UNITED STATES HISTORY

L. F. STOCK, J. J. MENG

The editing of volume VI of the *Proceedings and debates of the British Parliaments respecting North America* has progressed with many interruptions and discouragements, which are to be expected during wartime, when libraries and offices must be placed under emergency restrictions. But the work has gone forward

and this volume of the series is expected to be ready for the press during the coming year.

It is not now possible to say how far beyond 1763 the materials will carry. They certainly will cover all parliamentary references to the Seven Years' War and through the concluding peace of Paris. It is hoped that the limits of the volume will permit also the inclusion of the record of the passage of the Stamp Act through Parliament. The materials on this subject have been made ready for the printer, but the annotations are not yet completed, and the mass of text covering the act is so abundant that it may not be possible to carry the volume so far, especially since the French and Indian War was likewise the subject of extensive action and debate in both houses.

It is likely that during the coming year some decisions will be reached by the Chairman of the Division and the editor of these volumes which may change somewhat the editorial policy of presenting these texts, but which by way of compensation will make more certain the completion of the series in a form which will be entirely adequate for the purposes of students and writers who have made wide use of the volumes.

During the year Mr. Stock has, as usual, replied to many letters asking for historical information, and has given of his time to assist research workers who have come to Washington. He was made an honorary member of the American Catholic Historical Society, Philadelphia, and an advisory editor of the new historical journal, *The Americas*. He has lectured twice (in Washington and Philadelphia) on phases of his work. He represented the Institution at the inauguration of the Rt. Rev. Patrick J. McCormick as rector of the Catholic University of America.

The past year saw the publication of volume II of the *Guide to materials for American history in the libraries and archives of Paris*, dealing with the archives of the Ministry of Foreign Affairs. Volume III, including descriptions of various military and naval archives, is complete in manuscript. The fourth volume of this series is all but finished, requiring but a few weeks' work to bring it to an end. It deals with the National Archives, and lists the Acts of Sovereign Power, extracted from various depositories and described as a unit. Work on the fifth and final volume will be started before the summer is over.

Difficulties of printing and binding will prevent publication and distribution of volumes III, IV, and V until the conclusion of hostilities, or until the book-manufacturing situation is eased somewhat. The complicated task of editing and research is being continued by Dr. John J. Meng under the direction of Dr. Waldo G. Leland.

#### HISTORY OF SCIENCE

GEORGE SARTON

*Introduction to the history of science.* The manuscript of volume III was completed at the end of 1943 and accepted for publication by the Institution in February 1944. Its preparation for the printers has entailed many additional queries and minor investigations. As the book is enormous and the indispensable indexes will require considerable time, it can hardly appear within the next academic year, but we hope it may appear before the end of 1945.

*Editing of Isis.* Government orders concerning the economy of paper decreased the capacity of *Isis*, yet publication in double columns compensated to some extent for that decrease and we were able

to publish four numbers (nos. 96 to 99), including 35 main articles, 41 notes, 64 reviews, and 1430 bibliographic items, illustrated with 5 plates and 46 figures in the text. It has not yet been possible to resume the publication of *Osiris*.

The proofreading and editing of *Isis* are taken care of by Dr. A. Pogo, who also conducts many investigations not only for *Isis* and the *Introduction*, but also for other departments of the Institution. He continued his correspondence with members of our and other institutions, on calendrical and astronomical subjects; this correspondence involves the preparation of tables and of diagrams, the editing of type-scripts, etc.

*Ancient science down to Epicurus.* As Dr. Sarton had foreseen that some time would elapse between the submission of the manuscript of volume III of the *Introduction* and the arrival of the first proofs, he began the redaction of a new book devoted to the origins and development of Greek science to the end of the fourth century B.C. The best part of the summer of 1944 was devoted to the most difficult chapters, dealing with Egyptian and Babylonian science. As soon as the proofs of volume III begin to arrive, the writing of this work will have to be stopped until publication of that volume.

This book on ancient science will complete volume I of the *Introduction*, which began with Homer. The account of pre-Hellenic science is entirely new and the treatment of Hellenic science differs from that in volume I of the *Introduction*, in which attempt was made to speak, however briefly, of every scientist and of every scientific achievement. In the new volume no attempt is made to cover the whole ground, but the most important subjects will be discussed more thoroughly.

## PUBLICATIONS

MARGARET W. HARRISON

The eighth volume of "Contributions to American Anthropology and History" (Publication 546) was completed and distributed early in 1944. In the preceding six months the last three papers in this volume were preprinted: *Explorations in the Motagua Valley, Guatemala* (no. 41), by A. Ledyard Smith and A. V. Kidder; *The astronomical tables of the Maya* (no. 42), by Maud W. Makemson, of the Department of Astronomy, Vassar College; and *The Mercado, Chichen Itza, Yucatan* (no. 43), by Karl Ruppert.

Although printing was finished in December 1943, the binding of Ralph L. Roys' *The Indian background of colonial Yucatan* (Publication 548) was delayed by war demands until May 1944. This volume, first in a series of historical studies on the Maya area, will be followed by *Acalan-Tixchel: a contribution to the history of the Chontal Indians of southwestern Campeche*, the text of which is now being written by France V. Scholes and Mr. Roys in collaboration.

Three major publications are in press. For Tatiana Proskouriakoff's album of Maya architecture and sculpture (Publication 558), thirty-six gravure plates have been printed, and fifty-eight details and sketches and a map have been engraved. The text is ready for composition, and it is expected that the book will go to final press in September. The illustrations for *The Maya Indians of east-central Quintana Roo* (Publication 559), by Alfonso Villa R., are engraved, and proof of the text has been received. Composition has begun on *The textiles of highland Guatemala* (Publication 567), by Lila M. O'Neale, professor of decorative art at the University of California, Berkeley.

Dr. Kidder has almost finished writing

the manuscript of his report on Kaminaljuyu and much of it has been edited. A report on El Baul, Guatemala, has been received from J. Eric S. Thompson for publication as a Contribution to American Anthropology and History.

Volume I of "Notes on Middle American Archaeology and Ethnology" closed in December 1943 with the addition of nine papers since last year's report. Title page, table of contents, and index accompany the volume, which comprises notes 1-30. Two numbers, as well as the index, came from the editor of the series, J. Eric S. Thompson, and one from Dr. Kidder, all listed in the bibliography at the end of this report. Specialists outside the Institution contributed the remaining papers: *The periods of tribute collection in Moctezuma's empire* (no. 23), by R. H. Barlow; *Notes on Glyph C of the lunar series at Palenque* (no. 24), by Heinrich Berlin; *Notes on a west coast survival of the ancient Mexican ball game* (no. 26), by Isabel T. Kelly; *Animal-head feet and a bark beater in the middle Usumacinta region* (no. 27) and *New photographs and the date of Stela 14, Piedras Negras* (no. 28), by Linton Satterthwaite, Jr., of University of Pennsylvania Museum; and *A vase from Sanimituca, Alta Verapuz, Guatemala* (no. 30), by Elsie McDougall. Volume II began in January with two numbers by Stanley H. Boggs: *A human-effigy pottery figure from Chalchuapa, El Salvador* (no. 31) and *A preconquest tomb on the Cerro del Zapote, El Salvador* (no. 32). Heinrich Berlin supplied *A tentative identification for the head variant for eleven* (no. 33), and Karl-Heinz Nottebohm contributed *A possible lunar series on the Leyden Plate* (no. 34).

Mr. Thompson published in March 1944 a second paper, *The fish as a Maya symbol for counting and further discussion of*

*directional glyphs*, in the series "Theoretical Approaches to Problems," of which he is editor.

The second volume of the *Guide to materials for American history in the libraries and archives of Paris* (Publication 392)

was issued in January. Working under the general editorship of Waldo G. Leland, John J. Meng has compiled and edited the material for this volume as well as for the remaining ones in this series, which will be cumulatively indexed when completed.

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## SPECIAL PROJECTS: HISTORICAL RESEARCH

MARION E. BLAKE, Bradford, Vermont. *Preparation of a monograph on ancient Roman construction based on the material accumulated by the late Dr. Esther B. Van Deman.* (For previous reports see Year Books Nos. 38 to 42.)

The year 1943-1944 has brought the monograph based on the research of Dr. Esther Van Deman to the threshold of completion. The preface has been written. The entire text has been worked over for the elimination of needless repetition and the discrepancies inevitable in a study carried on over a period of years. Only a few odds and ends await final investigation. Frequent summaries within the text have obviated the necessity of a final chapter of recapitulation. Consequently the entire text is practically in final form. Practically all references have been checked. Significant quotations from the classical authors have been added to the footnotes. The card index of places has been completed and checked, and a second one of

subject matter is well in hand. The bibliography, though still in card-index form, is virtually complete. Considerable sporadic thought has been given to the matter of illustrations, but a short period of undivided attention will be necessary before the final choice of photographs is made and the plates are arranged for publication.

In a certain sense this whole volume is furnishing merely the necessary background for the study of the brick-faced concrete of imperial Rome, which was Dr. Van Deman's chief contribution to archaeological discovery. It is greatly to be hoped that it may be followed in the not too distant future by a second volume dealing with the masonry of the imperial period, for which it has paved the way.

## PALEONTOLOGICAL, GEOLOGICAL, AND HISTORICAL RESEARCH

JOHN C. MERRIAM, President Emeritus, Carnegie Institution of Washington. (For previous reports see Year Books Nos. 20 to 42.)

In reports on President Emeritus research of recent years, effort has been made so far as possible to bring to conclusion work on problems involving technical detail which should be made of record for use in future related researches. It is assumed that the conclusions from interlocking results attained in a wide variety of researches have large importance. It has also been considered as of relatively large importance to examine the conclusions from these researches in the light of their bearing upon major human problems. Though it is realized that in last analysis the value of any results which may be discussed will depend upon accuracy and adequacy of conclusions, it is also true that the values derived from varying types of researches frequently have greatly increased value when they are brought into relation to one another with particular reference to their use in consideration of human relations.

### RELATIVE IMPORTANCE OF JOHN DAY PROJECT

As has been indicated in earlier reports, one of the largest and most widely reaching fields of study toward which the investigations of the past years have been devoted is that relating to the group of problems presented by the John Day region of eastern Oregon, these studies having been carried on for a period now amounting to more than forty-five years. In the report of 1942-1943, development of the program in its major phases was outlined both as to results already obtained and as to the future of these researches as they were being developed in

the hands of a number of outstanding investigators. There are left, therefore, for consideration at the present time mainly general questions having to do with ultimate significance of the John Day program, the steps which have been taken to safeguard the work of the future, and the relation of these investigations and their results to the educational program of the state of Oregon.

The John Day region of Oregon contributes much to our understanding of a large group of factors involved in the general field of geological, geographical, and historical features of America. From the purely scientific point of view, it furnishes with exceptional clearness the story of a considerable portion of *geological time*, involving actually most of the sections of time known as the Tertiary and the Quaternary. Although there are other regions in which the geological story presented has at least a comparable extent through time, there are few if any areas in which the elements of the chapters presented are so nearly continuous and in which the varied features are so closely linked.

It happens also that the picture of earth history furnished by the John Day region represents an area which was in its *location* intermediate between what is now the great interior or plains area of America, and, on the other side, the extremely interesting and important section now known as the Pacific coast region of North America. From another point of view, the John Day region is important in that it shows as interlocked or interfingered a series of chapters of geological history

which present on one hand the story of *sedimentation*, represented by various types of water-laid and wind-laid formations, and on the other hand a vast accumulation of materials which represent *igneous activity* in various forms, and the types of rocks which such processes produce. Again, this region presents a very spectacular series of chapters in the history of the earth through *representation of land life* of the western half of the continent for a very long period, in which extensive and interlocking records were formed, preserving for our examination long series of remains of life types expressing the evolutionary development of forms ranging from a large variety of plants up to and through wide groups of the higher animals, including carnivores, herbivores, and other types in abundance.

From still another point of view, the John Day region, viewed as an expression of forms of nature, shows us a wide range of art values in *scenic features* characteristic of what is commonly known as a semiarid or desert region. Wide stretches of semiarid and highly sculptured landscapes show certain land forms in their most striking moods. With these varied aspects of form there is also a play of light and shade which is seen more effectively in the desert than in any other region, and in many areas there is the added contribution of great variety in color. To the student of varying forms and striking landscapes of the arid or semiarid type, the John Day region will have much to contribute as a source of elements of interest and beauty needed in our education on aspects of nature.

#### CLASSIFICATION OF ACTIVITIES RELATING TO ORGANIZED JOHN DAY STUDIES

As indicated in the report of 1942-1943, major objectives of the John Day program

are as follows: (1) the continuance of research activities upon problems of importance relating to that region for so long a time as such investigations may appear technically and humanly profitable; (2) organization of activities relating to contribution of John Day materials to the educational plan of the state and of the nation; (3) protection for scientific, educational, and economic uses of major features of the John Day region, which for their highest values should be safeguarded under authority of the state.

By authority of the Board of Higher Education of the state of Oregon, especially through the interest of Chancellor Frederick M. Hunter, there has been set up a committee known as the *Advisory Board on Educational Problems of Parks in Oregon*, which has as its primary function investigation of questions having to do with educational and scientific problems arising out of the study of natural features. In recognition of the importance of work which has developed in the John Day region with relation to research and education, the Advisory Board has become sponsor for an organization designed to give highest value to work in that area. The various activities relating to the John Day region are supervised, under the main Advisory Board, by an Executive Committee consisting of Warren D. Smith, chairman; L. S. Cressman, vice-chairman; E. L. Packard, and R. W. Chaney. Its main objectives are those outlined above, namely, *promotion of research, publication of materials of general interest to the public, and preservation and protection of the major features of interest*.

Of these three activities, that designed to promote continuation of research for the future, so far as this may be desirable, has centered in the setting up of a body known as the John Day Associates, com-

prising persons who have been associated with the work and with one another in the past or who will be related to it in the future. It is assumed that new members will be appointed by this body as persons are found showing specific interest in John Day problems and qualified to carry research forward on a high level. So important has this particular group appeared that it has been given special status by action of the Board of Higher Education. As now organized, there are eleven or twelve members, of whom L. S. Cressman, of the University of Oregon, is executive officer. The group includes a number of distinguished investigators, among whom are R. W. Chaney, Howel Williams, E. L. Packard, Ira Allison, John P. Buwalda, Chester Stock, and L. E. Detling. The John Day Associates will not improbably become one of the most important agencies in the state of Oregon for the advance of research, and may establish a pattern for corresponding groups having as their function the continuing of research activities relative to regions or features for which one may not expect the whole of any program to be worked out or completed within less than a generation.

The group designed to give attention to preparation of simple but accurate and interesting publications which may be made available to the people of the state and of the nation has been organized with four members, R. W. Chaney, Howel Williams, E. L. Packard, and J. C. Merriam, with R. W. Chaney, a distinguished investigator, thoroughly familiar with the whole John Day program, as chairman.

The third group, concerned with problems having to do with protection or preservation of areas or features of the John Day region possessing special scientific and educational importance, will be guided by a committee including R. W. Leighton as chairman; L. S. Cressman;

S. H. Boardman, superintendent of Oregon State Parks; Judge Robert Sawyer, formerly member of the Highway Commission and one of the principal promoters of the state park system of the state of Oregon; and E. P. Leavitt, superintendent of Crater Lake National Park. Activities relating to this objective must of necessity develop through action by the State Highway Commission, which includes the organization and supervision of state parks as a part of its responsibility. In the state highway group, S. H. Boardman, superintendent of State Parks, has been extremely interested and active in development of a program for protecting what seem to be the highest values in the John Day region.

The State Highway Commission has been interested and sympathetic in carrying forward this program in such manner as to make ultimate action fully effective for the future. The state already has title to about 1500 acres of land in the John Day region, representing some of the outstanding scientific, educational, and scenic features, and there is under consideration the securing of several thousand acres additional, which it is hoped may be so organized as to bring the various special values within a few unified areas so that they can be administered and utilized to best advantage. Fortunately, the elements of greatest interest in the John Day region are located in or along the valley of the John Day River, through which there passes a fine state highway, making it possible so to group the features of greatest interest that they may not only be protected effectively, but may be accessible readily to the public.

It is important to note that there is a strong undercurrent of interest in development of activities of this character in the state of Oregon, and that one may depend ultimately upon the interest and good judgment of the citizens of the state in

furthering whatever tends to bring about the best education of the people relative to the features of nature which are particularly interesting and important.

#### APPEAL OF NATURAL FEATURES OF JOHN DAY TO THE PUBLIC

In the last analysis, the interest of the public in these features by the path of what may be called self-education must be recognized as one of the most important avenues for approach. It is, therefore, desirable to inquire what the influence of characteristic features of the John Day may be upon visitors who have not had scientific training.

A large part of the scientific and human value of the John Day region is due to the fact that the things of particular interest are rather closely grouped along the walls of the John Day Canyon. The visitor finds that the canyon walls exhibit a considerable number of formations appearing as a complicated picture, with the parts in the same relation to one another now that they had when they were formed in past geological periods. The fact that this long and complicated story is presented clearly and realistically by the original formations, with their contents, is so striking that it attracts attention and invites inquiry on the part of all who visit the area.

In entering the John Day Valley, attention of the visitor is commonly attracted first of all by the fact that the region is essentially a sharply cut canyon, evidently excavated by the river. He also observes in the walls the cross section of many groups of rocks which appear to be steps in building the mass of strata. These sections of the accumulated pile are seen to vary considerably in character and in position with relation to one another.

Almost unavoidably it is realized that the topmost group of layers, which are

in general practically horizontal, seem to be continuous in whatever direction one follows them up to the region of Picture Gorge. This formation is seen to be made up of an alternation of hard and soft layers. The harder layers will by most persons be recognized as rock of a type abundant in the Northwest, generally known as lava, or the cooled remains of great flows of once melted rock. The softer parts are in general of the character of volcanic ash or mud. These lava flows form a striking scenic feature of this entire region.

The layers beneath the lava flows vary considerably in thickness, in color, in texture, and in position, some being practically horizontal and others sharply tilted. The contact between these layers is sometimes of such a nature as to make it evident that the upper part of a layer had been removed before the next succeeding one was laid down upon it.

In other regions of the John Day country, as at Picture Gorge, the great lava flows have been bent downward sharply so as to form a wide trough, in which later formations have been deposited, thus continuing the geological story practically up to the present time. Fortunately these later formations are also cut by the John Day Valley, so that their story is seen as a continuation of that in the rocks below the great lava flows.

If the visitor extends his study of this region sufficiently far to include examination of materials entombed in the various formations of the John Day Valley, he finds in these rocks many remains representing the skeletons or hard parts of various kinds of animals that inhabited the region when these formations were being laid down. Among these remains many types of life are represented, ranging from the lower forms to higher animals including such

creatures as horses, camels, rhinoceroses, sabre-tooths, and mastodons. In other layers will be found clear impressions of the stems and leaves with flowers and fruit of many kinds of plants.

It is evident to the visitor that there is here a series of rock formations which, having come into their present position in ages past, have remained in the relation to each other which they occupied at the time they were laid down. It is seen that the position of these formations with relation to one another expresses changes in the surface of the earth as affected by movements of the earth's crust in past periods. Examination shows also that the varying materials of which the several formations are composed reflect climatic and other physical conditions that obtained in this region at the time these layers were being deposited.

A fairly careful study, such as could be carried out by any person of intelligence, would show also that the remains of life in the several formations are not uniformly distributed, but the types in each series of layers are somewhat different from those in the strata above and below. This succession of remains presents, then, the evidence of a gradually changing series of living creatures in this region. That the change was gradual is indicated by the fact that types of life in adjacent beds are frequently similar, in other words are only different forms of the same group. The varying characteristics of the related life types in the successive formations represent changes through the ages which are commonly described as evolution.

We find, then, here a clearly shown succession of formations in which the materials indicate in some measure the changing physical conditions under which the rocks were formed, and in these formations we obtain remains of types of life varying through the ages, and presenting

to us what we recognize commonly as evolutionary series.

It is evident that we not only have still to learn the ways in which these things of interest in nature may be presented to visitors most effectively, but in addition, in many cases we have still to learn what the problems mean in the sense of scientific interpretation. In a relatively large number of cases it appears that what is most needed now may be more intensive research, with clear expression of the results, so that the interpreter may feel sure, first of all, that he understands what the question means fundamentally in terms of science; and, second, that he is aware of interests which may be developed by visitors; and, third, that he envisages a method by which the nature of the problem, the setting of the special features considered, and the point of view of the visitor may all be linked in such manner as to make possible the appreciation and enjoyment of these aspects of nature.

The value of the natural features in the John Day region is of special importance in connection with education of the public, by reason of the fact that the story as a whole illustrates basic principles underlying the development or evolution of the earth. To the average interested person these things are likely to have significance also as bearing upon questions concerning development of the human family or group. It becomes, therefore, desirable to ascertain so far as this may be possible the more fundamental meaning of these natural features. In nearly all cases where we examine closely into the significance of natural phenomena, we find that our understanding is evidently not fully adequate, and beyond the field of our vision there appear to be certain fundamental values which we interpret only in part. It seems clearly a responsibility of science at this time to attempt to get a clearer

understanding of the basic truths underlying natural phenomena, and to develop a better statement as to the relation of what we know to the fundamental things that are only partly revealed.

#### OUTSTANDING VALUES OF JOHN DAY FEATURES

We find, then, that, among many other things of value, acquaintance with the John Day Valley contributes three things of exceptional importance: first, the view of a *spectacular scenic area*; second, some understanding of *problems involved in building of the earth*; and, third, a *vision of the history of life and its evolution* seen in relation to the processes of earth building and shaping.

*Spectacular scenic values.* The scenic values of the John Day Valley are important both in relation to development of certain aspects of artistic representation of that region, and because scenic features not uncommonly are in part an expression of great underlying forces. It is important to give opportunity for consideration of scenic values, lest in the effort to construe what is seen in terms of science the values of the artistic and aesthetic and sublime be overlooked.

*Problems of earth building.* The problems of earth building as presented in the John Day area are extremely significant, by reason of the fact that an exceptional story of closely connected elements representing events in earth construction has been preserved through a long series of stages in building and shaping of this portion of the earth's crust, to be held together finally and protected until the whole section was opened to view by cutting of the John Day Canyon.

Whereas in many places on the earth we find extremely important and wonderfully expressed sequences of stages in earth

building, these examples are commonly spread out over considerable areas, so that study of the details must be approached by mapping and measurement of the formations in order that the data may all be assembled for a review of the stages presented in the landscape. But in the John Day Valley this longer story is presented to us in spectacular cliff sections so fitted together as to lead to an unavoidable series of conclusions such as is rarely possible in geological work. In the John Day section we not only see the final statement of a geological story of earth building, but we have opportunity also to examine in detail nearly all the processes involved, with particular relation to their expression of physical laws which we recognize as practically unvarying and dependable through time and space. Although the problem of earth building as presented by the John Day Valley is complicated, and might in some ways be said to be difficult of comprehension, it is nevertheless presented in such clear manner, owing in part to the imprint of that phase of the picture which we call scenic value, that the principal elements of the story are carried over to the person of average intelligence with a measure of conviction which is generally satisfying, and which is not shaken by further investigation.

*History of life and its evolution.* In the great field of constructive ideas which have been brought into being through cooperation of science and philosophy and education in recent generations, there is perhaps no concept or point of view that has had greater influence, either in theory or in immediate human practice, than has the broad philosophy of evolution, seen as the growth of the living world through time with the continuing tendency to development of more intelligent and more effective forms of life. Although this view

of movement of the living world is based upon ideas from many fields of biology, geology, and philosophy, it appears that the fundamental idea as it presented itself to Darwin rested mainly upon what he had found in a great succession of geological formations in which the types of life were seen to change from age to age. In other words, the theory was basically biological, but was read out of the paleontological-geological book.

In recent periods the theory of evolution has had enormous influence upon a vast range of things in the scientific, philosophic, and also the practical world about us. It is not improbable that the most important applications are yet to be made, when, after the present emergency, the world begins to find itself, and to see that development of close relations among human groups can ultimately be based upon the solid rock of relationship of the whole human family, as shown by study of its descent or development or evolution. If what is stated in this paragraph justifies itself, then we may properly consider that one of the most important contributions of the whole John Day story as we see it is that which gives us *a vision of life through the ages*, changing from stage to stage, showing at the same time continuity, variation, and development.

There are many places in the world where parts of this story may be read with assurance of accurate interpretation. There are few if any regions where the story is seen more clearly, and with a more effective picture of the background, than is true in the John Day section. It is not improbable that future generations will make of that region a Mecca, to which will come many who desire to see with their own eyes and to form judgments with their own minds upon the significance of the

idea that *life through the ages, under the guidance of whatever power there is behind nature, has tended to link the element of continuity with change, development, and progress.*

#### ADDRESSES BY DR. MERRIAM

"Perspective of time and change in relation to area and language," address before Area and Language group of military students, University of Oregon, Eugene, Oregon, September 21, 1943.

Address on recent research in eastern Oregon, before geology-geography seminar, University of Oregon, Eugene, Oregon, April 17, 1944.

"Exploration in the John Day region of eastern Oregon," Natural History Society of Eugene, Oregon, April 28, 1944.

"Science and revelation," Friends of the Library, Eugene, Oregon, May 6, 1944.

Radio address on "Science and the world order," with H. G. Townsend and Warren D. Smith, May 18, 1944.

"Development of cultural and social values through relation of science to other major fields of activity," talk before journalism class, University of Oregon, Eugene, Oregon, May 22, 1944.

"Exploration in the John Day region of eastern Oregon," Oregon Roadside Defense Council, Portland, Oregon, May 26, 1944.

Discussion on "Major objectives of national parks as illustrated by activities of Crater Lake National Park," before staff of Crater Lake National Park, Crater Lake, Oregon, August 16, 1944.

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Year Book No. 42, 1942-1943. Octavo, xxxii+10 +208 pages, 3 text figures.

392. LELAND, WALDO G., general editor. Guide to materials for American history in the libraries and archives of Paris. Volume II, Archives of the Ministry of Foreign Affairs, by WALDO G. LELAND, JOHN J. MENG, and ABEL DOYSET. Octavo, xii+1078+(1) pages. (Papers of the Division of Historical Research.)

545. SVERDRUP, H. U., F. M. SOULE, J. A. FLEMING, and C. C. ENNIS. Observations and results in physical oceanography. Quarto, vii+156 pages, 59 text figures. (Department of Terrestrial Magnetism, J. A. Fleming, Director. Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under Command of Captain J. P. Ault. Oceanography—I-A.)

546. Contributions to American Anthropology and History, volume VIII. Quarto, iii+260 pages, 1 frontispiece, 1 map, 1 diagram, 128 figures.

40-42. See Year Book No. 42 (1942-1943).

43. RUPPERT, KARL. The Mercado, Chichen Itza, Yucatan. Pages 223-260, 35 figures.

548. ROYS, RALPH L. The Indian background of colonial Yucatan. Octavo, viii+244 pages, 6 maps, 23 figures.

551. Contributions to Paleontology. Octavo.

I. See Year Book No. 42 (1942-1943).

II. HALL, E. RAYMOND. A new genus of American Pliocene badger, with remarks on the relationships of badgers of the northern hemisphere. Pages 9-23, 2 plates, 2 text figures.

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FREDERICK H. SEARES, Astronomy

GEORGE L. STREETER, Embryology

### RESEARCH ASSOCIATES CONNECTED WITH OTHER INSTITUTIONS

V. BJERKNES (University of Oslo), Meteorology  
EDWARD L. BOWLES (Massachusetts Institute of Technology), Physics  
JOSEPH C. BOYCE (New York University), Physics  
RALPH W. CHANEY (University of California), Paleobotany  
A. H. COMPTON (University of Chicago), Physics  
TH. DOBZHANSKY (Columbia University), Genetics  
FRANK T. GUCKER, JR. (Northwestern University), Chemistry  
ROSS G. HARRISON (Yale University), Biology  
ARTHUR T. HERTIG (Boston Lying-in Hospital), Embryology  
VICTOR F. HESS (Fordham University), Physics  
THOMAS H. JOHNSON (Bartol Research Foundation), Physics  
S. A. KORFF (Bartol Research Foundation), Physics  
E. A. LOWE (The Institute for Advanced Study), Paleography  
ROBERT A. MILLIKAN (California Institute of Technology), Physics  
†T. H. MORGAN (California Institute of Technology), Biology  
WALTER H. NEWHOUSE (Massachusetts Institute of Technology), Geophysics  
ROBERT REDFIELD (University of Chicago), Anthropology  
HENRY N. RUSSELL (Princeton University), Astronomy  
H. C. SHERMAN (Columbia University), Nutrition  
JOEL STEBBINS (University of Wisconsin), Astronomy

\* Retired in 1945.

† Deceased.

## OFFICES OF ADMINISTRATION

### *Office of the President*

**VANNEVAR BUSH, President**  
**WALTER M. GILBERT, Executive Officer**  
**SAMUEL CALLAWAY, President's Secretary**

### *Office of Publications and Public Relations*

**FREDERICK G. FASSETT, Jr., Director**  
**AILENE J. BAUER, Assistant to the Director**  
**DOROTHY R. SWIFT, Editor**

### *Office of the Bursar*

**EARLE B. BIESECKER, Bursar**  
**J. STANLEY LINGEBACH, Assistant Bursar**

### *Investment Office (New York City)*

**PARKER MONROE, Investment Officer**  
**RICHARD F. F. NICHOLS, Assistant Investment Officer**

## ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use, and in recent years a total of ten million dollars has been paid by the Carnegie Corporation of New York as increase to the Endowment Fund of the Institution. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications and Public Relations provides means for appropriate publication.

## ARTICLES OF INCORPORATION

PUBLIC No. 260. An Act to incorporate the Carnegie Institution of Washington.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

- (a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.
- (b) To appoint committees of experts to direct special lines of research.
- (c) To publish and distribute documents.
- (d) To conduct lectures, hold meetings, and acquire and maintain a library.
- (e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws

## ARTICLES OF INCORPORATION

shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinafter referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or

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any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

*Approved, April 28, 1904*

## BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, December 10, 1937, December 15, 1939, December 13, 1940, and December 18, 1942

### ARTICLE I

#### THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.
2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.
3. No Trustee shall receive any compensation for his services as such.
4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

### ARTICLE II

#### MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee.
2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.
3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

### ARTICLE III

#### OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.
2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

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3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

ARTICLE IV

EXECUTIVE ADMINISTRATION

*The President*

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

## BY-LAWS OF THE INSTITUTION

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

### ARTICLE V

#### COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication. The Executive Committee shall have power to authorize the purchase, sale, exchange, or transfer of real estate.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of

## CARNEGIE INSTITUTION OF WASHINGTON

expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

## ARTICLE VI

### FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

## ARTICLE VII

### AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

## ABSTRACT OF MINUTES OF THE FORTY-SEVENTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in New York, N. Y., in the Board Room of the Carnegie Corporation of New York, on Friday, December 14, 1945. It was called to order at 11:00 A.M. by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: James F. Bell, Robert Woods Bliss, Lindsay Bradford, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Frank B. Jewett, Alfred L. Loomis, Roswell Miller, Henry S. Morgan, Seeley G. Mudd, Henning W. Prentis, Jr., Elihu Root, Jr., Henry R. Shepley, Richard P. Strong, Charles P. Taft, Juan T. Trippe, James W. Wadsworth, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Vannevar Bush, was also in attendance.

The minutes of the forty-sixth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The Chairman announced the death of the President Emeritus, and upon motion it was

*Resolved*, That the Board of Trustees of the Carnegie Institution of Washington hereby records its deep regret at the death, on October 30, 1945, of Dr. John Campbell Merriam, President of the Institution from January 1, 1921 to December 31, 1938 and President Emeritus from January 1, 1939 until his death. Already distinguished as a brilliant student and notable contributor to his chosen field of paleontology and already recognized as a leader in organization of scientific programs, Dr. Merriam brought to the Institution qualities of mind and of humanity which resulted in profound advances in knowledge within the Institution and more broadly throughout the whole realm of science. By repeated emphasis on biological phenomena, he became a rare philosophic interpreter of nature and natural resources in their effects upon human thought and human aspirations. He led the Institution into new channels of scientific endeavor; and by his sympathetic understanding of human relationships, by his discriminating selection of investigators of exceptional ability, by his kindly insistence upon cooperative effort, he molded the various divisions within the Institution into an effective unit for furtherance of human knowledge. Dr. Merriam broadened and strengthened the concept of the Institution as an instrument of utmost value to society in the initiation and support of research. To the members of the Board of Trustees, Dr. Merriam was more than the wise leader and able investigator; he was friend and counselor. The members therefore record a profound personal regret at his death but rejoice that he has left so forceful and lasting an imprint upon the scientific endeavors of the Institution.

The following appropriations for the year 1946 were authorized:

Pension Fund .....	\$95,000
Administration (including expenses of Investment Office and of Insurance)	109,472
Publications (including expenses of Office of Publications and Public Relations)	64,000
Departmental Research Operations ..	<u>1,062,366</u>
	\$1,330,838

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Mr. Gifford was elected Chairman of the Board, Mr. Root was elected Vice-Chairman, and Mr. Delano was re-elected Secretary, each for the ensuing period of three years.

Robert Woods Bliss, Henry R. Shepley, and Lewis H. Weed were re-elected members of the Executive Committee for a period of three years.

Walter S. Gifford, Elihu Root, Jr., and Frederic C. Walcott were re-elected members of the Finance Committee for a period of three years.\*

Frederic A. Delano, Homer L. Ferguson, and James W. Wadsworth were re-elected members of the Auditing Committee for a period of three years.

The meeting adjourned at 12:40 P.M.

\* At the meeting of the Executive Committee following the annual meeting of the Board, Mr. Gifford submitted his resignation as a member of the Finance Committee, and Henry S. Morgan was appointed to take his place until the next annual meeting.

## REPORT OF THE EXECUTIVE COMMITTEE FOR THE YEAR ENDING OCTOBER 31, 1945

*To the Trustees of the Carnegie Institution of Washington:*

**GENTLEMEN:** Article V, section 3 of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, section 3 provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1945.

During this year the Executive Committee held five meetings, printed reports of which have been mailed to each Trustee and constitute a part of this report.

A statement of activities of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. Requests for use of facilities and resources of the Institution in carrying on war research under contracts with the Government have resulted in full-time operation of many departments of the Institution in the national interest. During the past year active work has been completed on most of the Government contracts entered into by the Institution. Thirty-eight projects have been undertaken during the past five years in the interest of war activities, and all but ten of these projects, still requiring some months of further work, have been completed. These activities are covered by 140 contracts, orders, or amendments, by means of which a total amount of four and a quarter million dollars has been made available for reimbursement to the Institution for out-of-pocket expenses. The Institution's own contribution in performing these research tasks for the Government has consisted of loan of space and equipment, of service by members of the scientific and executive staffs without cost to the Government, and of allotments aggregating about \$100,000 to cover special needs and services. The contribution which the Institution has made to the Government in the form of services by members of its scientific and executive staffs would have added approximately a million dollars to Government contracts if the Government had paid for such services. Furthermore, there has been no charge for overhead expenses in connection with the Institution's own part of the work.

The detailed estimate of expenditures for the succeeding year contained in the report of the President has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Continued attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1946, and budget recommendations are based upon the judgment of these committees with respect to financial policy in the post-war period.

The Board of Trustees, at its meeting of December 15, 1944, appointed Price, Waterhouse and Company to audit the accounts of the Institution for the fiscal year ending

October 31, 1945. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1945, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1945, showing funds available for expenditure and amounts allotted by the Executive Committee, a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, and a schedule of real estate and equipment at original cost. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

No vacancy exists in the membership of the Board of Trustees.

Tenure of office of the following officers of the Board of Trustees will expire at the annual meeting in December: Mr. Forbes, Chairman of the Board; Mr. Gifford, Vice-Chairman of the Board; and Mr. Delano, Secretary of the Board. Tenure of office of Messrs. Bliss, Shepley, and Weed as members of the Executive Committee; of Messrs. Gifford, Root, and Walcott as members of the Finance Committee; and of Messrs. Delano, Ferguson, and Wadsworth as members of the Auditing Committee will also expire at the annual meeting.

W. CAMERON FORBES, *Chairman*  
VANNEVAR BUSH  
ROBERT WOODS BLISS  
FREDERIC A. DELANO  
WALTER S. GIFFORD  
HENRY R. SHEPLEY  
FREDERIC C. WALCOTT  
LEWIS H. WEED

*November 1, 1945*

FINANCIAL STATEMENT FOR FISCAL YEAR ENDING OCTOBER 31, 1945

	Balances unallotted Oct. 31, 1944	Trustees' appropriations Dec. 15, 1944	Transfers and other credits	Total available	Executive Committee allotments	Transfers by Executive Committee	Unallotted balances Oct. 31, 1945
<b>Departmental Research Operations:</b>							
Embryology	...	\$78,552	\$9,500.00	\$88,052.00	\$88,052.00	...	...
Genetics	...	114,710	18,000.00	132,710.00	132,710.00	...	...
Nutrition Laboratory	...	18,610	...	18,610.00	18,610.00	...	...
Geophysical Laboratory	...	14,8523	...	148,523.00	148,523.00	...	...
Historical Research	...	119,583	...	119,583.00	119,583.00	...	...
Mount Wilson Observatory	...	203,330	...	203,330.00	203,330.00	...	...
Plant Biology	...	67,080	...	67,080.00	67,080.00	...	...
Terrestrial Magnetism	...	214,080	7,160.00	221,240.00	221,240.00	...	...
Research Projects of Limited Tenure	\$12,232.65	...	10,500.00	22,732.65	22,732.65	...	\$5,732.65
Publication	525.85	48,700	14,833.38	64,059.23	46,804.44	...	17,254.79
Administration	...	128,492	7,500.00	135,992.00	135,992.00	...	...
Pension Fund	...	75,000	...	75,000.00	75,000.00	...	...
General Contingent Fund	108,075.24	...	221,174.80	329,250.04	7,400.00	\$265,910.00	55,940.04
Carnegie Corporation Emergency Fund	266,772.15	...	...	266,772.15	16,230.00	18,500.00	232,042.15
	<b>\$387,605.89</b>	<b>\$1,216,660</b>	<b>\$288,668.18</b>	<b>\$1,892,934.07</b>	<b>\$1,297,554.44</b>	<b>\$284,410.00</b>	<b>\$310,969.63</b>

**AGGREGATE CASH RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1945**

RECEIPTS	DISBURSEMENTS
<i>Securities Sold or Redeemed</i> . . . . .	\$98,797,301.59
<i>Interest from Securities and Bank Balances</i> . . . . .	53,499,343.27
<i>Sales of Publications</i> . . . . .	369,915.32
<i>Colburn Estate (Bequest)</i> . . . . .	52,015.74
<i>Harriman Fund (Sale of Land)</i> . . . . .	4,043.70
<i>Teeple Estate (Bequest)</i> . . . . .	6,160.62
<i>Carnegie Corporation of New York (Endowment Increase and for Specific Purposes)</i> . . . . .	13,680,381.24
<i>From Other Organizations and Individuals for Specific Purposes</i> . . . . .	430,749.38
<i>Pension Fund (Refunds)</i> . . . . .	96,303.35
<i>General Reserve Fund</i> . . . . .	1,972.04
<i>Insurance Fund (Refunds)</i> . . . . .	13,076.02
<i>National Defense Revolving Fund (Refunds and Advances)</i> . . . . .	2,632,587.72
<i>Administration Building Addition Account, Rentals and Refunds</i> . . . . .	18,021.09
<i>Employees' Salary Deductions for the Purchase of U. S. Bonds</i> . . . . .	68,570.40
<i>Miscellaneous Refunds and Receipts</i> . . . . .	1,095,637.46
	<i>Securities Purchased</i> . . . . .
	<i>Accrued Interest on Securities Purchased</i> . . . . .
	<i>Pension Fund</i> . . . . .
	<i>General Reserve Fund</i> . . . . .
	<i>Insurance Fund</i> . . . . .
	<i>Harriman Fund</i> . . . . .
	<i>Special Emergency Reserve Fund</i> . . . . .
	<i>National Defense Revolving Fund</i> . . . . .
	<i>General Contingent Fund</i> . . . . .
	<i>Carnegie Corporation of New York Emergency Fund</i> . . . . .
	<i>Administration Building and Addition:</i>
	<i>Construction and Site (Old Building)</i> . . . . .
	<i>Construction (Addition to Administration Bldg.)</i> . . . . .
	<i>Site (Addition to Administration Building)</i> . . . . .
	<i>Miscellaneous Expenditures*</i> . . . . .
	<i>Departmental Research Operations:</i>
	<i>Departments of Research, Buildings and Equipment</i> . . . . .
	<i>Departmental Operations</i> . . . . .
	<i>Research Projects of Limited Tenure</i> . . . . .
	<i>Publication</i> . . . . .
	<i>Administration</i> . . . . .
	<i>Employees' U. S. Bond Purchases</i> . . . . .
	<i>National Research Council</i> . . . . .
	<i>Miscellaneous</i> . . . . .
	<i>October 31, 1945, Cash in Banks</i> . . . . .
	\$113,765,601.37
	<i>729,215.95</i>
	<i>1,616,543.24</i>
	<i>30,477.43</i>
	<i>140,532.24</i>
	<i>203.28</i>
	<i>63,819.41</i>
	<i>2,729,396.32</i>
	<i>292,521.66</i>
	<i>76,248.64</i>
	<i>309,915.69</i>
	<i>416,206.07</i>
	<i>68,570.96</i>
	<i>40,825.37</i>
	<i>3,921,706.68</i>
	<i>33,796,279.42</i>
	<i>5,519,905.72</i>
	<i>2,942,897.87</i>
	<i>2,993,932.32</i>
	<i>67,357.90</i>
	<i>150,000.00</i>
	<i>9,008.82</i>
	\$169,881,166.36
	<i>1,084,912.58</i>
	\$170,766,078.94

**\* Includes Equipment \$7,206.41, Repairs and Alterations to Old Building \$18,599.29.**

**REAL ESTATE AND EQUIPMENT, ORIGINAL COST**

**Administration (October 31, 1945)**

*1530 P Street, N.W., Washington, D. C.*

Building, site, and equipment.....	\$847,746.01
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**Division of Plant Biology (September 30, 1945)**

*Stanford University, California (Headquarters)*

Buildings and grounds.....	\$74,125.72
Laboratory.....	40,655.01
Library.....	26,518.42
Operating equipment.....	14,043.22
	<hr/> 155,342.37

**Department of Embryology (September 30, 1945)**

*Wolfe and Madison Streets, Baltimore, Maryland*

Library .....	\$4,498.38
Laboratory .....	19,561.44
Administration.....	7,989.55
	<hr/> 32,049.37

**Department of Genetics (September 30, 1945)**

*Cold Spring Harbor, Long Island, New York*

Buildings, grounds, and field .....	\$293,071.35
Operating equipment.....	34,089.25
Laboratory apparatus .....	38,352.99
Library .....	54,568.64
Archives.....	45,488.90
	<hr/> 465,571.13

**Geophysical Laboratory (September 30, 1945)**

*2801 Upton Street, N.W., Washington, D. C.*

Building, library, and operating appliances .....	\$292,267.05
Laboratory apparatus .....	171,304.96
Shop equipment .....	21,103.00
	<hr/> 484,675.01

**Division of Historical Research (September 30, 1945)**

*10 Frisbie Place, Cambridge, Massachusetts*

Operating equipment.....	\$28,797.96
Library .....	15,020.90
	<hr/> 43,818.86

**Nutrition Laboratory (September 30, 1945)**

*29 Blackfan Street, Boston, Massachusetts*

Building, office, shop, and library.....	\$134,613.93
Laboratory apparatus .....	31,828.84
	<hr/> 166,442.77

**Mount Wilson Observatory (September 30, 1945)**

*Pasadena, California*

Buildings and grounds .....	\$222,458.33
Shop equipment .....	48,976.14
Instruments .....	685,363.21
Furniture and operating appliances .....	153,194.77
Hooker 100-inch reflector .....	638,529.83
	<hr/> 1,748,522.28

**Department of Terrestrial Magnetism (September 30, 1945)**

*5241 Broad Branch Road, N.W., Washington, D. C.*

Building, site, and office.....	\$257,838.42
Survey equipment .....	94,016.62
Instruments, laboratory, and shop equipment.....	473,429.85
	<hr/> 825,284.89
	<hr/> \$4,769,452.69

## REPORT OF AUDITORS

*To the Board of Trustees  
Carnegie Institution of Washington  
Washington, D. C.*

We have made an examination of the attached balance sheet of Carnegie Institution of Washington (and supporting schedule of securities owned) as of October 31, 1945 and the related statement of operating income and expenditures for the fiscal year then ended. In connection therewith, we obtained confirmations from the custodian, Guaranty Trust Company of New York, as to the securities owned by the Institution and held in safekeeping at October 31, 1945 and from the depositaries as to the cash balances in banks at that date. The interest maturing during the fiscal year on bonds owned was accounted for, and the dividends received during the year on stocks owned were compared with published dividend records. With respect to a period of three months selected by us the recorded cash receipts were traced to deposits shown on the bank statements and paid checks and approved vouchers were inspected in support of the head office disbursements. We did not visit the branch offices of the Institution but we reviewed internal audit reports of the Bursar covering examinations of the branch records during the year and it appeared that the internal audits were satisfactorily conducted. We also inspected certified copies of the minutes of meetings of the Board of Trustees and the Executive Committee with respect to the appropriations and allotments for the year.

The securities are stated at cost, amortized cost or value at date acquired. In accordance with a recommendation made in February 1940 by the Institution's Finance Committee, premiums on bonds purchased subsequent to January 1, 1940 are being amortized on a straight-line basis to the dates on which the bonds are first callable or payable at par. The amortization of such premiums applicable to the year ended October 31, 1945 amounted to \$5,955.59. Real estate and equipment are stated at cost, and books on hand for sale are carried at sales prices. In accordance with accepted practice no provision has been made for depreciation of property owned by the Institution.

In accordance with established custom of the Institution, the budget appropriations are made for the calendar year, whereas the annual financial statements are prepared for the fiscal year ending October 31. In previous years the balance of estimated income applicable to November and December was included in the assets of the General Fund as at October 31 preceding and the unexpended appropriations and allotments for the same period were reflected in the current obligations in the balance sheet. Estimated income and approved appropriations and allotments for November and December 1945 are not reflected in the attached balance sheet as at October 31, 1945.

In our opinion, with the foregoing explanations, the accompanying balance sheet and related statement of operating income and expenditures present fairly the position of Carnegie Institution of Washington at October 31, 1945 and the financial aspects of its operations for the year ended on that date.

PRICE, WATERHOUSE & Co.

*Washington, D. C.  
November 26, 1945*

**BALANCE SHEET OCTOBER 31, 1945**

ASSETS		LIABILITIES	
<i>Investments</i>			
Securities . . . . .	\$38,559,260.05		
Cash: . . . . .	503,872.43		
Awaiting investment . . . . .	63,833.67		
Reserved for current needs . . . . .			
<i>Property Accounts</i>			
Real estate and equipment, at cost: . . . . .			
Office of Administration . . . . .	\$847,746.01		
Departments of research . . . . .	3,921,706.68		
<i>General Fund</i>			
Cash: . . . . .	\$517,206.48		
General account . . . . .	51,442.00		
Departmental bank balances . . . . .	500.00		
Petty cash and stamps . . . . .			
Accounts receivable (includes reimbursable expenditures of \$161,823.76 from U. S. Government, per contra) . . . . .			
Books on hand at sale price . . . . .	186,639.90		
Outstanding accounts on sales of publications . . . . .	162,804.80		
Paper in stock for future publications . . . . .	140.82		
	414.41	919,148.50	
<i>Endowment and Other Funds</i>			
<i>Capital Funds</i>			
Endowment Fund . . . . .		\$32,000,000.00	
Colburn Fund . . . . .		103,310.80	
Capital Reserve Fund . . . . .		4,440,604.16	
Harriman Fund (excluding \$179,628.05 included in Property Fund below) . . . . .		350,845.61	
Teepie Fund . . . . .		6,160.62	
		\$36,900,921.19	
<i>Special Funds</i>			
Pension Fund . . . . .		\$231,274.94	
Harriet H. Mayor Relief Fund . . . . .		10,000.00	
General Reserve Fund . . . . .		1,534,770.02	
Current funds invested (see below) . . . . .		450,000.00	
		2,226,044.96	
			\$39,126,966.15
<i>Property Fund</i>			
Income invested . . . . .		\$4,539,824.64	
Harriman property (gift) . . . . .		1,179,628.05	
			4,769,452.69
<i>General Fund</i>			
Current obligations and commitments: . . . . .			
Departmental research operations . . . . .		\$140,353.45	
Research projects of limited tenure . . . . .		28,164.68	
Publication . . . . .		48,810.09	
Administration . . . . .		16,876.78	
General Continental Fund . . . . .		63,891.00	
Carnegie Corporation Emergency Fund . . . . .		259,166.39	
Employees U. S. Bond Purchase Fund . . . . .		1,212.50	
Annuity premium deposits . . . . .		60.20	
Excess of advances received on U. S. Government contracts over disbursements made thereon . . . . .		55,726.37	
National Defense Revolving Fund (includes reimbursable expenditures of \$161,823.76 from U. S. Government carried in accounts receivable, per contra) . . . . .		300,000.00	
Unexpended and unallocated current income . . . . .			
			291,527.01
<i>Less</i> —Current funds invested (see above) . . . . .			
			\$1,205,788.47
			450,000.00
Value of publications and invoices . . . . .			\$755,788.47
Publication paper in stock . . . . .			162,945.02
			414.41
			919,148.50
			\$44,815,567.34

**GENERAL FUND**

**Statement of Operating Income and Expenditures for the Fiscal Year Ended October 31, 1945**

<b>Income:</b>			
Interest and dividends on securities.....		\$1,368,018.87	
<i>Less</i> —Amortization of bond premiums.....		5,955.59	
		<hr/>	
Sales of publications.....		\$1,362,063.28	
Carnegie Corporation of New York—grants.....		6,146.26	
Other credits.....		13,000.00	
		22,366.19	\$1,403,575.73
<b>Expenditures:</b>			
Pension Fund—annuity and insurance.....		\$123,879.57	
Carnegie Corporation Emergency Fund—grants.....		8,230.00	
Harriman Fund—commissions.....		43.12	
General Contingent Fund.....		6,785.70	
Departmental research operations:			
Salaries.....	\$627,463.92		
Operating expenses.....	148,854.55	776,318.47	
		<hr/>	
Research projects of limited tenure:			
Salaries.....	\$21,281.90		
Operating expenses.....	15,115.74	36,397.64	
		<hr/>	
General publication:			
Salaries.....	\$2,114.91		
Expenditures .....	11,043.52	13,158.43	
		<hr/>	
Office of publications:			
Salaries.....	\$16,007.09		
Operating expenses.....	1,760.79	17,767.88	
		<hr/>	
Administration expenses.....		119,381.05	
		<hr/>	
<i>Less</i> —Salaries and operating expenditures charged to previous appropriations.....		\$1,101,961.86	
		173,837.84	928,124.02
		<hr/>	
Excess of income over expenditures.....			\$475,451.71
<i>Less</i> —Credits to General Reserve Fund and other accounts.....			183,924.70
		<hr/>	
Unexpended and unallocated current income.....			\$291,527.01

SCHEDULE OF SECURITIES OWNED OCTOBER 31, 1945

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired	Market value	Interest income for year
<b>UNITED STATES GOVERNMENT BONDS</b>					
U. S. of America Treasury 2 $\frac{1}{2}$ %		1951-49	\$304,000.00	\$312,740	\$6,080.00
312,000		1951-49	312,000.00	320,970	6,240.00
200,000		1952-50	200,000.00	205,875	4,000.00
4,500,000		1954-52	4,500,000.00	4,657,500	43,442.38
800,000		1955-52	800,000.00	838,250	18,000.00
520,000		1962-59	524,846.38	524,225	(838.42)
1,239,000		1962-59	1,243,438.79*	1,315,276	30,975.00
350,000		1967-63	350,000.00	360,172	8,750.00
75,000		1968-63	75,000.00	76,664	1,875.00
1,200,000		1969-64	1,200,000.00	1,224,000	30,000.00
400,000		1969-64	400,000.00	407,900	10,000.00
50,000		1953	50,000.00	47,350	1,250.00
50,000		1954	50,000.00	47,400	1,250.00
50,000		1955	100,000.00	95,600	2,500.00
100,000		1955	100,000.00	96,900	2,500.00
100,000		1956	100,000.00	98,800	1,250.00
100,000		1957	2,701,372.88	2,700,837	(8,520.49)
2,700,000			...		10,308.79
Income from bonds sold					
Total U. S. Government					
<b>\$13,050,000</b>			<b>\$13,060,638.35</b>	<b>\$13,377,609</b>	<b>\$175,312.46</b>
<b>FOREIGN BONDS</b>					
Canadian National Ry. Co. 4 $\frac{1}{2}$ % Guar.		1951	\$90,219.54*	\$102,600	\$4,050.00
Canadian National Ry. Co. 4 $\frac{1}{2}$ % Guar.		1957	112,000.00	119,000	4,500.00
Canadian National Ry. Co. 5% Guar.		1969	61,727.76*	66,120	2,850.00
Canadian Pacific Railway Co. Perpetual Cons. Deb. 4 $\frac{1}{2}$ s		1970	31,766.58*	40,000	1,750.00
Province of Alberta Deb. 4 $\frac{1}{2}$ s		1958	264,475.00	318,000	12,000.00
Province of Alberta Deb. 5s		1950	93,750.00	120,000	2,250.00
Province of Manitoba Deb. 4 $\frac{1}{2}$ s		1952	101,150.00	121,000	1,250.00
Province of Nova Scotia Deb. 4 $\frac{1}{2}$ s		1958	142,886.77	169,500	6,750.00
Shawinigan Water and Power Co. 1st Mtg. & Coll. Tr. S. F. 3 $\frac{1}{2}$ s		1952	100,312.50	104,000	4,500.00
City of Toronto Cons. Loan Deb. 5s		1970	201,963.64*	210,000	2,994.44
		1949	90,104.59	111,000	5,000.00
Income from bonds called					
<b>\$1,332,000</b>	Total Foreign		<b>\$1,302,416.38</b>	<b>\$1,481,820</b>	<b>\$53,519.44</b>

\* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940

**SCHEDULE OF SECURITIES—Continued**

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired	Market value	Interest income for year
<b>\$243,000</b>	<b>PUBLIC UTILITY BONDS</b>				
23,900	Columbus & Southern Ohio Electric Co., 1st Mtg. 3 1/4s	1970	\$259,068.40*	\$262,440	\$7,897.50
50,000	Commonwealth Edison Co., Conv. Deb. 3 1/4s	1958	23,910.75	30,831	836.50
40,000	Consolidated Edison Co. of N. Y., Deb. 3 1/4s	1948	50,875.00	51,000	1,750.00
100,000	Consolidated Edison Co., N. Y., Deb. 3 1/4s	1958	40,730.00	42,000	1,400.00
	Detroit Edison Co., Gen. & Ref. Mtg. 4s	1965	103,500.00	106,000	4,000.00
200,000	Gulf States Util. Co., 1st Mtg. & Ref. 3 1/4s	1969	213,500.00	216,000	7,000.00
200,000	Illinois Power Co., 1st Mtg. & Coll. Tr. 4s	1973	201,924.19*	210,000	8,000.00
200,000	Minnesota Power & Light Co., 1st Mtg. 3 1/4s	1975	204,920.00	210,000	(416.67)
50,000	Northern States Power Co., 1st Mtg. 3 1/4s & Ref. Mtg. 3 1/4s	1967	47,500.00	52,000	1,750.00
100,000	Ohio Power Co., 1st Mtg. 3 1/4s	1967	101,500.00	106,000	3,250.00
100,000	Ohio Public Service Co., 1st Mtg. 4s	1962	102,625.00	106,000	4,000.00
100,000	Oklahoma Natural Gas Co., 1st Mtg. 2 1/2s	1961	101,441.17*	103,000	2,875.00
200,000	Public Service Co. of Indiana, Inc., 1st Mtg. 3 1/4s	1975	204,920.00	212,000	(520.80)
125,000	Puget Sound Power & Light Co., 1st Mtg. 4 1/4s	1972	129,896.46*	132,500	5,312.50
146,000	Southern Natural Gas Co., 1st Mtg. Pipe Line, S. F. 3 1/4s	1936	149,079.42*	153,000	4,745.00
250,000	Tennessee Gas and Transmission Co., 1st Mtg. Pipe Line, 3s	1965	255,625.00	255,000	(145.83)
120,000	Toledo Edison Co., 1st Mtg. 3 1/4s	1968	121,800.00	127,200	4,200.00
294,000	United Gas Corp., 1st Mtg. Coll. Tr. 3s	1962	294,000.00	297,760	7,423.50
190,000	Utah Power & Light Co., 1st Mtg. 3 1/4s	1968	191,113.27*	197,600	7,875.00
225,000	Wisconsin Electric Power Co., 1st Mtg. 3 1/4s	1968	232,875.00	238,300	7,875.00
	Income from bonds called or sold				62,923.19
<b>\$2,956,900</b>	<b>Total Public Utility</b>		<b>.....</b>	<b>.....</b>	<b>\$3,117,131</b>
					<b>\$141,279.89</b>
	<b>COMMUNICATION BONDS</b>				
<b>\$314,000</b>	American Telephone & Telegraph Co., Deb. 3 1/4s	1966	\$326,706.75	\$329,700	\$10,205.00
25,000	Mountain States Telephone & Telegraph Co., 3 1/4s	1968	25,500.00	26,500	812.50
52,000	New England Telephone & Telegraph Co., 1st Mtg. 5s	1952	51,748.00	58,760	2,600.00
	Income from bonds converted or sold				8,302.88
<b>\$319,000</b>	<b>Total Communications</b>		<b>.....</b>	<b>.....</b>	<b>\$414,960</b>
					<b>\$21,920.38</b>
	<b>RAILROAD EQUIPMENT TRUSTS</b>				
<b>\$52,000</b>	Pennsylvania R. R. Co., 2 1/2s Guar.	1956	\$81,283.64	\$84,460	\$1,947.50
<b>\$52,000</b>	Total Railroad Equipment Trusts	.....	.....	.....	<b>\$1,947.50</b>

\* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940.

SCHEDULE OF SECURITIES—Continued

Aggregate par or nominal value	Description	Maturity	Cost, amortized cost, or value at date acquired	Market value	Interest income for year
<b>RAILROAD BONDS</b>					
\$100,000	Chesapeake & Ohio Ry. Co., Gen. Mtg. 4 1/8s	1992	\$99,464 29	\$140,000	\$4,500.00
75,000	Chicago & W. Indiana R. R. Co., Cons. 4s	1952	70,357 66	81,000	3,000.00
200,000	Elie R. P. Co., 1st Cons. Mtg. 3 1/8s	1990	201,293 75*	202,000	886.40
100,000	Great Northern Ry. Co., Gen. Mtg. 5s	1973	104,385 84	134,000	5,000.00
50,000	Oregon Short Line R. R. Co., Cons. 1st Mtg. 5s	1946	48,405 15	51,000	2,500.00
75,000	Pennsylvania R. R. Co., Gen. Mtg. 4 1/8s	1965	75,918 75	92,250	3,315.00
100,000	Pittsburgh, Cln. Chi. & St. L. R. R. Co., Gen. Mtg. 5s Guar.	1960	104,662 50	124,000	4,500.00
50,000	Southern Rwy. Co., 1st Cons. Mtg. 5s	1975	51,898 98	66,000	2,500.00
100,000	Terminal R. R. Assn. of St. Louis, S. F. Gen. Ref. Mtg. 4s	1994	103,580 34	132,000	5,000.00
67,000	Toledo & Ohio Central Ry. Co., Ref. & Imp. Mtg. 3 1/8s Guar.	1953	60,878 03	73,700	2,680.00
100,000	Union R. R. Co., Deb. 6s Guar.	1960	99,000.00	103,000	3,750.00
2,084,000	West Shore R. R. Co., 1st Mtg. 4s Guar.	1946	2,084,000.00	2,167,360	125,040.00
100,000	Western Maryland Ry. Co., 1st & Ref. Mtg. 5 1/8s	1961	78,140 00	83,000	4,000.00
50,000	Income from bonds called or sold	1977	42,677.19	53,000	2,750.00
			..	..	14,277.78
<b>\$3,251,000</b>	<b>Total Railroad</b>		<b>\$3,224,662.48</b>	<b>\$3,502,310</b>	<b>\$183,759.18</b>
<b>INDUSTRIAL AND MISCELLANEOUS BONDS</b>					
\$100,000	Atlantic Refining Co., Deb. 3s	1953	\$102,347 98*	\$103,000	\$3,000.00
200,000	Eastern Gas and Fuel Associates, 1st Mtg. & Coll. Tr. 3 1/8s	1965	204,340 00	212,000	(972.22)
190,000	Empire Gas and Fuel Co., S. F. Deb. 3 1/8s	1962	176,403 12	191,900	6,650.00
300,000	B. F. Goodrich Company, 1st Mtg. 2 1/8s	1965	301,500 00	303,000	(68.83)
75,000	Greyhound Corporation, S. F. Deb. 3s	1959	75,870 54*	76,500	2,250.00
149,000	Phillips Petroleum Co., S. F. Deb. 2 1/8s	1964	150,378 41*	153,470	4,697.50
79,000	Railway Express Agency, Serial Notes 2 1/8s-2 3/8s	1945-48	79,000 00	79,000	1,803.75
300,000	Seagram (Joseph E.) & Sons, Inc., Deb. 3 1/4s	1955	306,000 00	315,000	(270.81)
371,000	Shell Union Oil Corp., Deb. 2 1/8s	1954	336,323 47	378,420	9,275.00
255,000	Socony-Vacuum Oil Co., S. F. Deb. 2 1/8s	1955	266,490 39*	269,610	7,417.50
75,000	Socony-Vacuum Oil Co., Deb. 3s	1964	78,000 00	79,500	2,250.00
	Income from bonds called		..	..	15,972.49
<b>\$2,097,000</b>	<b>Total Industrial and Miscellaneous</b>		<b>\$2,096,653.91</b>	<b>\$2,161,400</b>	<b>\$51,404.38</b>
<b>MORTGAGES</b>					
\$100,000	Lawyers Mtg. Co., Guaranteed 1st Mtg. Clfs. 4 1/4% No 29940T	1940	\$92,642 60	**	\$2,700.00
	Income from mortgages sold or liquidated				12,513.72
<b>\$100,000</b>	<b>Total Mortgages</b>	<b>...</b>	<b>\$92,642 60</b>	<b>**</b>	<b>\$15,213.72</b>
<b>\$23,259,900</b>	<b>BONDS AND MORTGAGES—Funds Invested</b>		<b>\$23,293,075.97</b>	<b>\$24,139,690</b>	<b>\$644,356.95</b>

\* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940.

\*\* In liquidation, market quotations not available.

## SCHEDULE OF SECURITIES—Continued

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
	<b>PREFERRED STOCKS</b>			
100	American Brake Shoe Co., 5 1/4% Cum. Pref. ....	\$12,653.50	\$12,900	\$525.00
2,304	American Cyanamid Co., 5% Cum. Pref. ....	28,059.62	27,544	1,252.00
1,500	Appalachian Electric Power Co., 4 1/4% Cum. Pref. ....	159,000.00	169,500	6,750.00
1,900	Armstrong Cork Co., 3 3/4% Cum. Pref. ....	195,250.00	205,200	.....
1,500	Bethlehem Steel Corp., 7% Cum. Pref. ....	183,637.50	226,500	10,500.00
1,500	Bristol Myers Co., 3 1/2% Cum. Pref. ....	158,734.38	163,500	1,406.25
1,800	Buffalo, Niagara & Eastern Power Corp., \$5.00 Cum. Pref. ....	112,225.00	119,000	.....
500	Case (J. I.) Co., 7% Cum. Pref. ....	62,225.00	79,500	3,442.98
600	Cleveland Electric Illuminating Co., \$4.50 Cum. Pref. ....	68,112.25	66,000	2,700.00
1,125	Continental Can Co., Inc., 8 3/4% Cum. Pref. ....	115,312.50	121,500	2,250.00
105	Corn Products Refining Co., 7% Cum. Pref. ....	19,400.00	19,950	551.25
1,000	Deere & Company, 7 7/8% Cum. Pref. ....	28,812.50	38,000	1,400.00
1,125	duPont (E. I.) de Noveurs & Co., \$4.50 Cum. Pref. ....	116,125.00	132,815	5,000.00
1,500	General Motors Corp., \$5.00 Cum. Pref. ....	187,931.50	190,500	7,500.00
1,300	Goodrich (B. F.) Co., \$5.00 Cum. Pref. ....	129,867.50	133,900	6,500.00
700	Goodyear Tire & Rubber Co., \$5.00 Cum. Conv. Pref. ....	73,150.00	79,100	3,500.00
1,000	Grant (W. T.) Co., 3 1/2% Cum. Pref. ....	100,447.91	108,000	937.50
220	Johns-Manville Corp., 3 1/2% Cum. Conv. Pref. ....	22,000.00	28,600	.....
1,090	May Department Stores Co., \$3.75 Cum. Pref. ....	113,291.91	116,630	2,043.75
1,500	McKesson & Robbins, Inc., \$4.00 Cum. Conv. Pref. ....	144,000.00	159,000	6,000.00
850	Minnesota-Honeywell Regulator Co., 4 1/4% Cum. Conv. Pref. ....	95,200.00	91,800	1,810.50
1,000	New York State Electric & Gas Corp., 5 1/10% Cum. Pref. ....	103,250.00	108,000	5,100.00
1,000	Northern States Power Co., \$5.00 Cum. Pref. ....	103,000.00	112,000	5,000.00
695	Ohio Power Co., 4 1/2% Cum. Pref. ....	76,552.00	79,925	2,964.39
1,000	Pacific Telephone and Telegraph Co., 6% Cum. Pref. ....	235,220.75	256,500	9,000.00
1,600	Panhandle Eastern Pipe Line Co., 4% Cum. Pref. ....	104,166.68	109,000	1,000.00
260	Philip Morris & Co., Ltd., Inc., 4 1/2% Cum. Pref. ....	171,731.50	176,000	3,200.00
600	Pittsburgh Mills, Inc., \$4.00 Cum. Pref. ....	92,631.00	92,020	2,135.00
2,000	Public Service Co. of Oklahoma, 5% Cum. Pref. ....	60,900.00	66,000	3,000.00
2,000	Reynolds (R. J.) Tobacco Co., 3 60/62% Cum. Pref. ....	199,683.75	208,000	.....
1,334	Servel, Inc., \$4.50 Cum. Pref. ....	225,250.00	220,000	4,500.00
250	Sherwin-Williams Co., 4% Cum. Pref. ....	124,985.95	125,874	1,134.00
1,500	United States Gypsum Co., 7% Cum. Pref. ....	45,187.50	48,000	1,312.50
3,100	U. S. Rubber Co., 8% Non Cum. 1st Pref. ....	184,337.50	244,500	12,000.00
	U. S. Steel Corp., 7% Cum. Pref. ....	443,407.57	433,800	21,700.00
	Income from stocks converted, called, or exchanged .....	.....	.....	31,999.87
40,858	Total Preferred Stocks .....	.....	.....	\$4,295,787.52
				\$4,628,918
				\$168,177.52

**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
<b>COMMON STOCKS</b>				
600	Air Reduction Company	\$35,968 38	\$29,400	\$1,600.00
1,700	American Cyanamid Co.	150,886 36	171,700	5,100.00
2,900	American Radiator & Standard Sanitary Corp.	90,321 12	133,400	5,075.00
1,800	American Telephone & Telegraph Co.	32,901 71	30,600	720.00
3,200	Armstrong Cork Company	472,918 99	598,400	18,170.00
1,800	Boston Edison Company	35,939 37	44,800	1,200.00
1,600	C. I. T. Financial Corporation	58,267 61	68,800	3,200.00
2,700	Caterpillar Tractor Co.	139,684.19	140,400	1,350.00
1,300	Chase National Bank of N. Y.	87,905 50	88,400	2,925.00
2,500	Chrysler Corporation	84,918 15	112,500	3,500.00
3,300	Cleveland Electric Illuminating Company	294,502 76	412,500	9,900.00
1,700	Coca-Cola Company	36,356 63	45,000	2,000.00
800	Colgate-Palmolive-Peet Company	92,163 75	126,000	2,800.00
2,500	Commercial National Bank and Trust Co. of N. Y.	23,217 66	34,400	1,500.00
2,100	Commonwealth Edison Company	108,152 78	127,500	4,000.00
3,000	Continental Can Co.	58,733 36	69,300	2,940.00
1,300	Continental Illinois National Bank & Trust Co. of Chicago	119,869 67	138,000	3,000.00
2,808	Continental Insurance Co.	111,236 66	150,800	5,200.00
6,000	Continental Oil Co. of Delaware	105,654 17	157,248	5,616.00
1,100	Corning Glass Works	162,943 08	210,000	9,000.00
2,100	Dowware Power & Light Company	27,500 00	38,500	2,750.00
600	Dow Chemical Co.	33,497 78	48,300	2,340.00
2,100	duPont (E. I.) de Nemours & Co.	12,657 09	90,600	1,800.00
600	Eastman Kodak Co.	371,330 73	444,000	12,600.00
1,093	First National Bank of N. Y.	337,422 75	462,000	13,650.00
75	Food Machinery Corporation	91,704 00	116,400	4,800.00
8,400	General Electric Co.	51,931 39	77,655	1,364.40
4,600	General Foods Corporation	328,655 07	394,800	13,020.00
7,200	General Motors Corporation	189,521 09	230,000	7,360.00
1,700	Goodrich (B. F.) Co.	369,589 82	532,800	21,600.00
1,400	Goodyear Tire & Rubber Co.	72,040 78	119,000	3,400.00
10,400	Grant (W. T.) Co.	54,800 38	85,400	2,800.00
9,100	Guaranty Trust Co. of N. Y.	177,153 63	301,600	5,280.00
1,700	Gulf Oil Corp.	119,782 55	168,080	16,975.00
8,200	Hartford Fire Insurance Co.	392,405 24	527,800	4,250.00
2,300	Humble Oil & Refining Co.	146,767 87	195,500	
1,166	Insurance Company of North America	245,069 64	377,200	
1,000	International Business Machines Corp.	172,486 59	250,700	
1,000	International Nickel Company of Canada, Ltd.	153,029 21	258,832	
1,000	Johns-Manville Corp.	30,588 46	33,000	
4,500	Kennecott Copper Corporation	96,629 23	138,000	
662	Kress (S. S.) Company	35,500 73	44,000	
1,900	Lawyers Mortgage Corp., Voting Trust Ctr.	103,455 81	153,000	
1,900	Liggett & Myers Tobacco Co., B	171,301 08	182,400	
1,300	Liquid Carbonic Corporation	34,177 35	49,400	
2,600	Merck & Co., Inc.	106,118 30	109,200	

*(Continued on following page)*

SCHEDULE OF SECURITIES—Continued

Number of shares	Description	Cost, amortized cost, or value at date acquired	Market value	Dividends for year
<b>COMMON STOCKS—Continued</b>				
1,500	Minneapolis-Honeywell Regulator Co.	\$58,930.51	\$79,500	\$1,875.00
2,500	Monsanto Chemical Co.	250,869.39	270,000	5,025.00
5,300	Montgomery Ward & Co.	253,876.10	360,400	10,400.00
4,700	National Cash Register Co.	135,674.89	183,300	5,875.00
1,000	National City Bank of New York	38,625.00	49,000	1,300.00
1,460	National Fire Insurance Co. of Hartford	84,378.41	89,060	2,920.00
225	National Union Fire Insurance Co. .	38,900.90	39,150	1,125.00
3,100	Newberry (J. J.) Co. . . .	164,239.94	294,500	7,440.00
2,500	New Jersey Zinc Co.	160,159.81	180,000	7,300.00
2,100	Owens-Illinois Glass Co. .	129,438.09	155,400	4,200.00
2,700	Fenney (J. C.) Co.	245,919.43	367,200	13,500.00
1,600	Pepsi-Cola Company	32,872.29	57,600	840.00
5,400	Phillips Petroleum Co.	262,565.68	270,000	7,200.00
1,300	Pittsburgh Plate Glass Co.	142,810.48	188,500	5,525.00
2,700	Procter & Gamble Co. .	151,181.83	175,500	5,400.00
1,500	Scot Paper Co. . . .	61,907.05	84,000	2,100.00
15,200	Sears, Roebuck & Co. .	301,538.07	562,400	16,150.00
4,600	Sharp & Dohme, Inc. .	64,873.96	96,600	2,300.00
1,600	Sherwin-Williams Co. .	157,573.57	214,400	6,000.00
1,700	Squibb (E. R.) & Sons	100,364.05	170,000	3,400.00
1,100	Standard Brands Incorporated	33,989.76	48,400	1,265.00
6,500	Standard Oil Co. of Indiana	193,467.24	266,500	9,150.00
4,500	Standard Oil Co. of New Jersey	232,971.92	288,000	11,250.00
4,200	Texas Company	92,614.25	125,400	5,500.00
3,600	Timken Roller Bearing Co.	173,837.79	219,600	7,200.00
3,000	Union Carbide & Carbon Corp.	253,960.66	288,000	9,000.00
70	Union Trust Company of Pittsburgh	117,587.88	131,600	2,922.00
2,800	United Fruit Company	207,853.85	319,200	11,200.00
2,200	United States Gypsum Co.	187,979.92	224,400	4,400.00
11,000	Westinghouse Electric Corp	288,374.69	385,000	2,750.00
2,200	Woolworth (F. W.) Co.	84,919.68	107,800	3,520.00
	Income from stocks sold or exchanged			125,135.00
224,484.75	Total Common Stocks	\$10,970,396.56	\$14,612,393	\$555,484.40
265,342.75	COMMON AND PREFERRED STOCKS—Funds Invested	\$15,266,184.08	\$19,241,311	\$723,661.92
	AGGREGATE INVESTMENTS (BONDS AND STOCKS)	\$38,559,260.05	\$43,381,001	\$1,368,018.87*

\* Represents total interest and dividend income before deduction of amortization of bond premiums.

NOTE: Net profits from sales and redemptions of securities for the year ended October 31, 1945 aggregated \$765,576.01, and that amount has been credited to the Capital Reserve Fund shown in the attached balance sheet.

REPORT OF THE PRESIDENT  
OF THE  
CARNEGIE INSTITUTION OF WASHINGTON  
FOR THE YEAR ENDING OCTOBER 31, 1945



REPORT OF THE PRESIDENT  
OF THE  
CARNEGIE INSTITUTION OF WASHINGTON

This report to the Trustees of the Carnegie Institution of Washington, made in accordance with the By-Laws, finds the Institution in a period of transition. Staff members are returning from war activities, and we look forward to peace.

The Institution can take satisfaction in the contribution it has made to the war effort. Many members of its staff have carried heavy responsibilities, in uniform and in the laboratories. Others whose professional talents could not be brought directly to wartime application have been equally unselfish in their participation as citizens in various forms of war work. The facilities of the Institution have been largely diverted to war research, with important results. In fact, one of the most striking technical developments of the war, which had a decided influence on the outcome, had its origin in the Institution early in the conflict. Radar arose from many sources, but from none more clearly than from early work in the Department of Terrestrial Magnetism on reflections from the ionosphere. Many of the staff, and of the Trustees as well, have served in the civilian scientific organizations concerned with war instrumentalities and war medicine, and the Administration Building has become the gathering place for the scientists of the country during its use as the focus of these activities. The effective relationships thus initiated will long continue on an informal basis.

With the return of peace there does not seem to be any obligation on the part of the Institution to continue military re-

search. Such research should continue; in fact it is essential that until the world can develop better ways of ensuring the safety of all peace-loving peoples, the nation maintain this highly important aspect of its efforts for security. But there are other organizations which are more naturally fitted for the task of supplementing the military research of the armed services themselves, because their normal programs lie closer to application. The primary responsibility of the Institution hence is to return to that basic scientific research which is its normal function, and which now needs increased emphasis after five years of drawing on scientific capital for the imperative task of making applications to war. For this reason the military research programs of the Institution are being closed out as rapidly as is consistent with the preservation of values already attained.

With the return of peace the several departments and divisions can take a fresh start. The programs of many of them have been so severely interrupted that they are practically beginning anew. We can look ahead, choose the lines of research in which the promise is greatest, and proceed. There need be no limitation to the choice of programs, other than that dictated by the extent of our resources and the nature of our talents, as we evaluate where our contributions to human knowledge will be most fruitful. We should choose deliberately and take proper time to do so, for the opportunity thus to choose may be rare, and it is none too easy to

## CARNEGIE INSTITUTION OF WASHINGTON

alter a program once it is embarked upon. There is no need for continuing a program merely because it has been a past activity. Neither should we allow labels to constrain us unduly. Certainly whatever we attempt should be such that every member of the staff can contribute substantially to some portion of it, and derive satisfaction in doing so. It is also clear that the Institution should ordinarily not pursue those objectives which can be pursued equally well or better by other organizations, for the Institution is unique in many ways. It has unique opportunities, and in general it should seek unique ends if it is fully to justify its existence and is to exert among research organizations of the country the beneficent influence which its position should ensure.

The programs of the several divisions should become formulated by the staffs of those divisions themselves. This condition is fundamental to the success of any undertaking in basic science. The President and the Trustees, of course, have the duty to review and approve, for the programs should measure up to certain over-all criteria, and there is moreover the obligation to ensure that the programs of various divisions become so interrelated that they may lend support one to another. In fact, in advance of review, consultation is very much in order, and it is hoped that in the months ahead there will be close contact between the members of the staff and the committees of the Board concerned with the various disciplines, either in joint meetings or in frequent informal individual discussions. But the staffs of the divisions, under the leadership of their several directors, will and should take the burden of analysis, comparison, initiation, and formulation, with the greatest freedom for the vision of individuals to be expanded and the aspirations of individuals

to be weighed. Out of such deliberations emerge sound programs which groups will pursue with enthusiasm.

Some of this will have to wait, for not all our absent members have yet returned. Moreover, we are weary, and brilliant plans are seldom formulated by tired men. It is well that there should be a respite, as the opportunity for vacation offers, before we turn fully to the making of plans. No time will be lost, for seldom does the time spent in contemplating a program of research before vigorously embarking upon it exceed what is wise and reasonable.

In planning, moreover, it is necessary that we take due note of what is going on in scientific research in the country as a whole. The war has brought great changes in this regard, and even the organizational forms under which research will be conducted in the future in this country will differ from those in use before the war.

The country is at last awake to the value of scientific research. It may indeed even be too much awake, for it was awakened rather violently, and there may hence be unwarranted distortions of view. There is certain to be plenty of emphasis on applied research in industry, governmental organizations, and universities and colleges, but it is not so certain that there will be sufficient emphasis on fundamental or pure research. Similarly there is bound to be emphasis on research in the physical sciences, because their applications have been spectacular, and on direct medical science for the same reason. It is not nearly so certain that every area where the scientific method can add to man's understanding of himself and his environment will be adequately explored.

This situation will probably be exaggerated because of the serious deficit which policies pursued during the war produced in the scientific manpower of the country.

The country learned fully of the importance of science, and of its application by engineers and industrialists, after the war, not before. Moreover, it did not grasp the fact that, in any rapidly altering technological field, the young men are often the only ones who fully comprehend some of the ramifications. Two principles governed our actions: one that every citizen should be ready to sacrifice equally in the common cause, and the other that every man should be used in the place where his talents could contribute most fully to the common effort. These principles were not in balance. As a result, by taking altogether too many trained young scientists and engineers out of the laboratories and industry, we very nearly wrecked that part of our war effort which consists in keeping the instrumentalities in the hands of our fighting men substantially superior to those of the enemy. We also sacrificed the future to immediate needs, more than did any of our allies or indeed our enemies, by halting our processes of advanced education, thus creating a lack of scientific manpower from which we shall not recover for many years. We are a strange country. As this is written we are at peace, but we are still doing both these things.

The result is that, as the Institution turns back to its normal functions, it will find the path difficult in many ways. The lack of a sufficient number of brilliant young men with a basic training in fundamental science will be particularly unfortunate. We need such men throughout the Institution; their presence will be good for them and also for us. I have discussed this point with many members of the staff and I find uniform agreement. No research program which proceeds without the benefit of the impact of young minds can expect long to remain virile. Few individuals can retain their creativeness fully

unless they are also engaged in teaching those who will follow in their footsteps and some day pass them on the road, and one of the finest types of teaching is that exemplified by the master surrounded by his disciples. There are many ways of finding such young men and of giving them opportunity to spend a few years with us. But we shall be severely hampered in the undertaking in the immediate post-war years, for there will just not be enough young men of talent to go around.

The vista ahead in science is, however, attractive indeed, if we can assume a peaceful world in which the energies of scientists need no longer be diverted, almost entirely, to activities necessary for military security. This is not so much because new opportunities have been opened during the war, for most of the war effort in science consisted in applying results in ways long familiar to scientific men. Rather it is because the great part which science and its application have played ensures that, taking the country as a whole, there will be adequate support for scientific effort in the future if the country remains prosperous. It is also due to another factor. Many a scientist has now applied himself assiduously for five years to tasks often far from his inclinations, assigned by the needs of the moment, and requiring his full energies. Yet the speculative mind has not been idle, even though it has been temporarily inhibited from entering those inviting trails that have been glimpsed in the midst of harassing and confining duties. Every brilliant scientist in the country's service probably has one or more of these prospects which he has promised himself he would pursue when the release came, and it has now come. We have had a partial moratorium on the creations of fundamental science, we have unwisely produced a deficit of scientific

## CARNEGIE INSTITUTION OF WASHINGTON

manpower, but we undoubtedly have a new stock of dammed-up ideas. It will be interesting to watch what happens as the dam breaks.

One further point should be made before we turn to definite planning. There is some fear prevalent, and there is basis for the fear, that the present emphasis on science may result in an unbalance in this country and a neglect of other fields of intellectual effort. The Institution is indeed directly interested in this matter, for since the extension of knowledge is not all by means of application of the scientific method, the field of the Institution has long included activities on the scientific borderland, or indeed in the humanities. Research has objectives that are broader than practical knowledge, immediate or potential, and involves those cultural aspects of knowledge which respond to the innate curiosity of the race, and its ponders in regard to its origins and possibly in regard to its destiny.

From a more practical point of view as well, it is important that no unbalance occur. We have entered a new world. It is a terrifying world perhaps, as we view the power of new forces which can destroy, but then the world has always been terrifying in many aspects to those who have really regarded it face to face, rather than substituted contemplation of an idealized model with some of the seamy aspects omitted. It is certainly, however, a world in which there is much need for courageous and intelligent thinking in every department of man's activities, not merely in the scientific field. It is a world in which young keen minds need to grapple with many phases of the common prob-

lem of keeping progress uninterrupted by such cataclysms as have twice jarred it within a generation, or by other disasters, for there are others that do not come under the heading of war. There is a problem before us, therefore: Will science become overenthusiastic and will other departments of intellectual endeavor suffer as a consequence?

The answer to this problem will not come through holding science back, or through requiring of it some self-denying restraint. It has too much to do, the national security and prosperity require its full efforts, and the vistas are much too attractive. The solution will not come from pulling down but from building up. Specifically, we need to educate fully in this country all the young brilliant minds that can be found, wherever they may be located and whatever their station. We have never done so nearly well enough. If we do there will be sufficient to man the various professions and intellectual pursuits, and as young men start their careers the various callings should be clearly presented so that none requiring recruits will be overlooked. We should not forget, for example, that political careers must be made fully attractive for sound thinkers if democracy is to function effectively in a world of growing complexity. This may not be directly the Institution's affair, for it is not primarily an educational institution, even though it has a function to perform in advanced scientific education of its own younger staff; but it is certainly an important matter, and in one way or another the Institution can perhaps lend a hand.

### FINANCES

The Institution has emerged from the war in sound financial condition. Its en-

dowment is in fact increased, because of the generosity of the Carnegie Corpora-

tion. Its investments have been safely managed thus far through a very difficult period.

It has conducted a large amount of war research for government under contract, on a basis where it contributed its facilities, its normal overhead, and the services of its regular staff, and was reimbursed only for out-of-pocket expenses for additional staff, equipment, and overhead. This policy has of course cost something, for there have inevitably been expenses that were not in either category, but the direct cost has not been large.

On the other hand, some of the amounts budgeted for support of departmental research programs have not been expended, on account of absence of staff members on war assignments with other organizations. These items have been reverted and placed in reserves where they will be available for the expenses of reconverting to normal activities. Though this expense will be substantial, for the equipment of the Institution will need attention after five years, the money thus placed in the reserve fund will apparently be sufficient for the purpose. The expenditure of this reserve awaits the return of the staff and the formulation of programs for the future.

It is difficult to foresee the future from a financial standpoint. In general it appears that, if the financial affairs of the country remain in sound condition, so also will those of the Institution. The rate of income from endowment has dropped

severely, but thus far this loss has been offset by additions to endowment, economies in operation, and the termination of matured programs. Still, either a further decrease in rate of income or a substantial rise in the cost of living would bring severe stress. Of course, a real inflation would wreck the Institution completely as well as the country generally, but there is no way for us to guard against such an eventuality except by our influence as citizens on the general trends.

If the pattern following World War I is repeated, we may expect a few years of abnormal costs of living and of operation, followed by a return to the long-time trends which preceded the war. If such a pattern repeats, we may well need to operate with a succession of deficit budgets and draw on our reserves, for we now have little margin in operations. This procedure would not be disastrous, if the period is actually temporary, for the condition of our reserves is excellent.

Entirely apart from the short-term trends, however, there is one point which needs our attention as soon as the financial outlook allows. The salary scale of the Institution is not, by and large, high enough in view of the position of the Institution among research organizations in the country. This disparity should be carefully and thoroughly corrected, even if in order to rectify it we must forego opportunities to enter new fields of research for some time.

#### NEW RETIREMENT PLAN

Restudy of the Institution's position with respect to retirement provisions has resulted in modification and restatement of our procedure for annuity and life insurance, and adoption of a revised Retirement and Insurance Plan which became effec-

tive on January 1, 1945. Specifications of the old plan have been modified to provide increase in joint contributions toward premiums on annuity contracts and to eliminate provision for supplementary annuity except in so far as supplementary aid

## CARNEGIE INSTITUTION OF WASHINGTON

may be required in the few cases in which the new provision for minimum retiring allowance becomes applicable.

It is hoped that the minimum provisions of the new plan will enable the average male member to retire with a single life annuity of about 40 per cent of final salary. This is a reasonable goal, but present actuarial and financial conditions require an increase in annual contributions to reach it. For new members the procedure is compulsory, with the provision that entrance of those of advanced age will be conditioned by agreement with the Institution concerning the extent of contributions which may be necessary to produce appropriate retirement benefits.

The new plan also offers opportunity to present members to increase their contributions to the minimum percentage required of new members. Many have taken advantage of this offer, and with policies which have prospect of low returns, such action has been particularly helpful. Furthermore, there is provision for extending the coverage of collective insurance. In this connection it should be noted that, if the United States Government author-

izes changes now contemplated in social security provisions, the Institution and its members may be called upon to participate, in which case further modification of our own Retirement and Insurance Plan will be in order.

Annual appropriations for the Pension Fund have been sufficient in the past to cover the Institution's contributions toward payment of premiums on annuity and collective insurance contracts as well as payments by the Institution in the form of supplementary annuity authorized by the old retirement plan. The peak of the supplementary annuity load has been reached, and obligations of this character will gradually diminish in the future. On the other hand, there is sharp increase in cost to the Institution of contributions toward premium payments on annuity contracts, as authorized by specifications of the new plan. It is estimated that a net increase of about \$20,000 in the annual appropriation for the Pension Fund will be required if this Fund is maintained as a reservoir from which we shall continue to make payments as in the past.

### RETIREMENTS AND CHANGES

Inauguration of a plan for joint action by the Institution and the California Institute of Technology in the future operation of the great astronomical centers at Mount Wilson and Palomar Mountain promises much positive accomplishment in this important field of research. The cordial informal cooperation which has existed between the Mount Wilson Observatory and the California Institute since the inception of the project for building a 200-inch telescope reaches maturity in the formulation of a unit scientific program for the observational work of the two observatories, to take effect as soon as the

Palomar equipment is completed, and in the reinforcing of this program by educational activities on the campus of the California Institute. Graduate training leading to the doctorate will be given under the auspices of the Institute by an astrophysics staff drawn from both the Institution and the Institute.

Thus the fortieth anniversary year of the Mount Wilson Observatory, witnessing the retirement on January 1, 1946, of its distinguished Director, Dr. Walter S. Adams, after more than two decades' service, witnesses also the institution of a plan calculated to extend in future the

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contribution to knowledge which has made the observatory notable in the past. Dr. Ira S. Bowen, Professor of Physics at the California Institute of Technology, known for his work in spectroscopy and astrophysics, will succeed Dr. Adams as Director. Elected to the Astronomy Section of the National Academy of Sciences in 1936, Dr. Bowen was awarded the Draper Medal in 1942 in recognition of his discoveries in astronomical physics.

The report of Dr. Thorne M. Carpenter as Director of the Nutrition Laboratory reviews in this Year Book an activity which during the past thirty-eight years has produced results of the highest importance in advancing knowledge of the nutritive processes in man. The program of the Laboratory, which was organized in 1907, grew out of metabolism experiments supported earlier by the Institution and out of needs for fundamental work in the general field of nutrition. The experimental studies were of pioneering value in dealing with fundamental laws governing vital activity as expressed in the chemical and energy transformations in the animal body. Directed by Dr. Francis G. Benedict from 1907 to 1937 and by Dr. Carpenter thereafter, the Laboratory made memorable contributions to knowledge of the physiological chemistry of the human body, to the development of instruments and techniques, and to the accumulation of physiological data concerning vital activities of normal man and of special

pathological cases as well. In recent years Dr. Carpenter and his small staff have effectively carried on programs of special war research.

It is thus after a noteworthy career that the activities of the Laboratory are being brought to termination with Dr. Carpenter's retirement, in pursuance of the policy which research organizations like the Institution must follow—of relinquishing work in which they have carried the initiative when the time comes that other organizations are prepared to continue it.

Growing in part out of the general correspondence which preceded the appointment of a new Director of the Office of Publications and Public Relations, and in part out of his study of the Institution's past publications and publication policies, basis has been laid for discussions by all interested members of the Institution's staff designed to consolidate policy and to consider expansion of the program so as to aid increasing the intelligent nonscientific citizen's comprehension of science. Plans are in preparation for the rearrangement and rehabilitation of the stocks of Institution publications, which have been disarranged because of unprecedented demands for space imposed by wartime uses of the Administration Building; better coordination of orders and shipping practices has already been achieved, and will be increased as present physical handicaps are removed.

### RESEARCH ACTIVITIES

Though the departments and divisions of the Institution have been to a great degree withheld by war research from vigorous pursuit of projects in their usual fields of interest, some regular research activities have been carried on. Since much of the Institution's investigation for war

purposes bears directly on problems with which it is engaged in normal times, many findings have been made in war programs which will be directly useful as regular programs are resumed.

At Mount Wilson, Dr. Walter S. Adams reports, the full observational program

## CARNEGIE INSTITUTION OF WASHINGTON

with solar instruments and with the 100-inch telescope has been conducted. Further study has been made of the so-called irregular sunspots which do not undergo change in magnetic polarity at the start of a new cycle. In the literature, these have been characterized as "small unstable groups," but the Mount Wilson study shows them to be as large and as stable as the spots which shift in polarity with the new cycle. Present preliminary results indicate, in fact, that their polarity is the only irregular feature of the so-called irregular spots.

The cyclotron of the Department of Terrestrial Magnetism has been in almost continuous daily operation for cooperative studies with the Naval Medical Research Center and the United States Public Health Service. These agencies and the Department have each contributed workers of special skills to the research teams carrying on this work.

The needs disclosed by experience as probable in any future research of the kind are discussed in detail in the thirteenth and final volume of "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929 under Command of Captain J. P. Ault," which has been completed for publication. Compilations of secular changes in the characteristics of the earth's magnetic field, described in the Year Book report for 1944, have been completed.

The volcano Parícutin in Mexico was visited by a representative of the Department of Terrestrial Magnetism for a preliminary survey for a program expected to be useful in the general problem of investigation of thunderstorms, and by a representative of the Geophysical Laboratory who went at the request of the Division of Geology and Geography of the National Research Council in order to obtain firsthand information upon which to ad-

vise the National Research Council group set up to coordinate studies of the volcano.

Oxidation of unsaturated fatty acids in the material has been found to be the source of the antibiotic properties of chlorellin, which was first isolated from cultures of the alga *Chlorella* in the Division of Plant Biology. As a result of this important discovery, Dr. Spoehr reports, other more direct sources of unsaturated fatty acids, such as corn, olive, and raisin oils, are now being utilized, and the oxidation reaction produced by exposure of them to air and light is under study. The *Chlorella* research, which of itself offered interesting possibilities in the development of antibiotic materials, thus has served as introduction to very promising fields. Since unsaturated fatty acids are available in such readily obtainable and relatively inexpensive source materials as vegetable oils, and since the mechanism of oxidation giving rise to antibiotic values is, though highly complex, susceptible of direct chemical study, the program is being stressed by the Division.

This Division's program of development of improved range grasses to produce more feed by better utilization of the soil and the growing season has resulted in the production of promising hybrids from which it is hoped to establish improved types. Testing of the more satisfactory hybrids—for example, one between Big bluegrass from eastern Washington and a hardy race of Kentucky bluegrass from Swedish Lapland—is being carried on at the Institution's mountain stations as well as at the central laboratory. Some are being delivered to the Soil Conservation Service for more extensive final testing.

Though published research of the Department of Embryology during the year past has been relatively small, because of

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the wartime scattering of workers, the main lines of the Department's work have been continued. The development of the Embryological Collection has progressed, instruments and techniques have been brought nearer final perfection, and other programs have been carried out in performance of the basic plan of research stated in Year Book 40.

Successful development, under a War Production Board contract, of a strain of *Penicillium* yielding a high content of penicillin was accomplished during the year in the Department of Genetics. Mutants produced by X-ray irradiation were screened to pick out exceptional high yielders rather than to screen out low yielders, about 10 per cent of the samples being retained. Of the 504 selected strains sent to the University of Minnesota for further testing, one, yielding about twice as much penicillin as the strain from which it originated, is now used in production.

The genetics of acquired bacterial resistance to drugs and other antibacterial agents is being studied in an extensive

program started in June 1945. Solving of practical problems arising from bacterial resistance to therapeutic agents, and attaining of fundamental knowledge of the mutational patterns of bacteria and the underlying physiological mechanisms, Dr. Demerec states to be the two purposes of the project. Work on resistance to penicillin, sulfonamides, inorganic salts, bacteriophages, and ultraviolet radiation is included.

Interruption of the field work of the Division of Historical Research and diminution of its staff by the war led to opportunity, which has been thoroughly utilized, for the organization and writing up of the results of various investigational programs. Dr. Kidder reports that definitive publication of several projects has thus been brought into immediate prospect. Reconnaissance investigations of several sites, for the collection of data, preparation of preliminary maps, and similar purposes, have been made during the year, in anticipation of the opportunity to resume field operations.



# REPORTS OF DEPARTMENTAL ACTIVITIES AND COOPERATIVE STUDIES

## ASTRONOMY

*Mount Wilson Observatory*

## TERRESTRIAL SCIENCES

*Geophysical Laboratory*

*Department of Terrestrial Magnetism*  
*Special Projects*

## BIOLOGICAL SCIENCES

*Division of Plant Biology*

*Department of Embryology*  
*Department of Genetics*  
*Nutrition Laboratory*  
*Special Projects*

## HISTORICAL RESEARCH

*Division of Historical Research*



## MOUNT WILSON OBSERVATORY

*Pasadena, California*

WALTER S. ADAMS, *Director*

The present year is the fortieth anniversary of the establishment of the Mount Wilson Observatory by the Institution. During this period progress in astronomy and especially in astrophysics has been extraordinary, in keeping with the great developments in atomic physics. In addition, our knowledge of the universe has increased remarkably, and the development of methods for studying matter in its various forms throughout the depths of space has been successful almost beyond belief.

The Observatory has contributed notably to many of these advances, particularly in the fields of solar and stellar physics, in that of cosmogony, and in the application of new methods and instruments to the solution of astronomical problems. Between the discovery of magnetism in the sun in 1908 and the development of the observational basis for the theory of the expanding universe in more recent years lie a multitude of discoveries which have aided in the interpretation of the intricate and fascinating aspects of the physical world. The Observatory has fulfilled in large measure the hopes and expectations of its founder and first Director, Dr. Hale, and of the Institution which supported his plans and ideals so fully and generously.

As the war reaches its end, scientific research will encounter many problems of readjustment, both material and psychological. In some respects the present is the beginning of a new epoch which will call for a close study, selection, and revaluation of the problems of physical science. This

is especially true of astronomy, to which the rapid development of new physical and optical methods and devices, and of great telescopes like the 200-inch reflector, will bring remarkable opportunities and corresponding responsibilities. It is with high anticipations for a future of great accomplishment that the present Director submits to the President and the Trustees of the Institution his last annual report of the activities of the Observatory.

The part taken by the Observatory in the study of various problems relating to the war has been especially extensive during the past year. In addition to previous contracts entered into with the Office of Scientific Research and Development, two new contracts have been undertaken. One of these is directly with the Army Air Forces; the second, under the Applied Mathematics Panel of the OSRD, has required a portion of the services of nearly the entire scientific staff. This contract has involved much statistical investigation.

With a single exception, all the members of the staff who have been on leave of absence for war investigations are still absent from the Observatory. As a result there has been some difficulty in carrying on the full observational program on Mount Wilson; but through the cordial cooperation of the remaining members of the staff it has been possible to maintain completely observations with the solar instruments and the 100-inch telescope. A few interruptions have occurred in the work of the 60-inch reflector.

## STAFF AND ORGANIZATION

## RESEARCH DIVISION

*Solar Physics*: Harold D. Babcock, Seth B. Nicholson, Joseph Hickox, Edison Hoge, Edison Pettit, Robert S. Richardson, Mary F. Coffeen, Elizabeth S. Mulders, Myrtle L. Richmond.

*Stellar Motions and Distances*: Adriaan van Maanen, Ralph E. Wilson,\* A. Louise Lowen.

*Stellar Photometry*: Walter Baade, Mary Joyner Seares.

*Stellar Spectroscopy*: Walter S. Adams, William H. Christie,\* Theodore Dunham, Jr.,\* Milton L. Humason, Alfred H. Joy, Paul W. Merrill, Rudolph Minkowski, Roscoe F. Sanford, Gustaf Strömberg, Olin C. Wilson,\* Ada M. Brayton, Sylvia Burd, Cora G. Burwell, Dorothy D. Locanthi,\* A. Louise Lowen.

*Nebular Photography, Photometry, and Spectroscopy*: Edwin P. Hubble,\* Walter Baade, Milton L. Humason, Rudolph Minkowski, Sylvia Burd.

*Physical Laboratory*: Robert B. King.\*

*Editorial Division*: Paul W. Merrill, editor; Elizabeth Connor, assistant editor and librarian; Alice S. Beach, secretary and stenographer.

Alfred H. Joy has continued as Secretary of the Observatory throughout the year.

## RESEARCH ASSOCIATES

Sir James Jeans, Dorking, England; Henry Norris Russell, Princeton University; Frederick H. Seares, Pasadena; Joel Stebbins, University of Wisconsin.

Dr. Russell has been actively engaged in the analysis of the neutral iron spectrum in collaboration with Mrs. Sitterly, and his advice and experience have been of great value in the preparation of the extensive Multiplet Table by Mrs. Sitterly, and of the Infrared Solar Spectrum by Babcock

and Mrs. Sitterly. The *Fe I* Table has been published and the other two catalogues are nearing completion. The solar material used in all three investigations has been provided from Mount Wilson.

Dr. Seares with the aid of Miss Joyner has completed an extensive analysis of the basic magnitudes of southern stars measured by Stoy at the Cape of Good Hope and has compared them with standards in the northern hemisphere. In addition, Dr. Seares and Miss Joyner have studied certain statistical problems arising in the course of the analysis.

The wave length of the strong infrared radiation in the night sky detected by Dr. Stebbins and Dr. Whitford several years ago has been measured by Stebbins with sufficient accuracy to enable Dr. Swings to establish its origin as molecular nitrogen. Dr. Stebbins has also completed photoelectric measurements of 238 stars of different spectral types in six regions of the spectrum. The results are most interesting in their bearing on space reddening and the distribution in wave length of stellar radiation as compared with that of a black body.

## TEMPORARY ASSOCIATES

Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, spent about six weeks of the summer of 1944 in Pasadena, continuing his observations of radial velocities with the 60-inch telescope.

Dr. John C. Duncan, Director of the Whitin Observatory, made numerous direct photographs of a variety of diffuse and planetary nebulae with the two reflectors during the summer of 1944 and compared some of the negatives with similar photographs made by him in 1921. Dr. P. Swings, professor at the University of Liége, has remained in Pasadena through-

\* On leave of absence for investigations relating to the war.

out the year and has carried on active studies in stellar spectroscopy during a portion of his time. These have resulted in important identifications of forbidden and highly ionized lines in several stars of peculiar spectrum, in the identification already mentioned of the strong infrared radiation at  $\lambda 10440$  in the night sky with a band of molecular nitrogen, and in numerous other interesting results.

Miss Suzanne van Dijke spent several of the summer and autumn months of 1944 in Pasadena, continuing her investigation of the spectral differences between giant and dwarf stars. Mr. W. C. Miller, of Pasadena, has continued the observations of bright-line B-type stars which he began several years ago with the 10-inch telescope, and has supplemented them with spectrograms he has obtained with the 60-inch reflector.

Several members of the Ballistic Research Laboratory of the Aberdeen Proving Ground were at the Pasadena offices of the Observatory during the autumn of 1944. A large measuring instrument was placed at their disposal and assistance was given in other ways.

#### INSTRUMENT DESIGN AND CONSTRUCTION

*Design:* Edgar C. Nichols, chief designer; Harold S. Kinney, draftsman.

#### OBSERVING CONDITIONS

Because of interruptions in the observing schedule, the detailed table showing the monthly record of observations with the 60-inch telescope is omitted. Solar photographs were obtained on 316 days between July 1, 1944 and June 30, 1945, and the 100-inch telescope was used on approximately 240 nights. In general, observing

*Optical Shop:* Donald O. Hendrix, superintendent.

*Instrument Shop:* Albert McIntire, foreman; Elmer Prall, instrument maker; Fred Scherff, Oscar Swanson, Albert Labrow, Donald Yeager, machinists; Harry S. Fehr, cabinet maker.

#### MAINTENANCE AND OPERATION

*Office:* Anne McConnell, bookkeeper; Dorothy Neuens, stenographer and telephone operator.

*Operation:* Ashel N. Beebe, superintendent of construction; Sidney A. Jones (on leave of absence for military service) and Kenneth de Huff, engineers; Thomas A. Nelson, Floyd Day, Louis S. Graf, Hobart Wright, night assistants; Ernest W. Hartong, truck driver and machinist helper; Anthony Wausnock, Mrs. Wausnock, and Mrs. Pauline Byers, stewards; Arnold T. Ratzlaff, Irving Angel, and Harry Sering, janitors.

Several of those whose names are listed above have been with the Observatory but a part of the year.

Numerous temporary additions were made during the year to the personnel of the optical and instrument shops and to the experimental laboratory outside of the Observatory buildings to provide for the government contracts undertaken by the Institution.

conditions were below the average, as is frequently the case when the winter season is abnormally cold. The total snowfall was 52 inches and the precipitation for the year 31.75 inches, 6.35 inches below the normal amount for Mount Wilson. More than one-half the snowfall came during the month of March.

## SOLAR RESEARCH

## SOLAR PHOTOGRAPHY

Solar photographs were made on 316 days between July 1, 1944 and June 30, 1945 by Hickox, Hoge, Nicholson, Pettit, and Richardson, as follows:

Direct photographs . . . . .	632
<i>Ha</i> spectroheliograms of spot groups, 60-foot focus . . . . .	576
<i>Ha</i> spectroheliograms, 18-foot focus	1,248
<i>K2</i> spectroheliograms, 7-foot focus .	10,700
<i>K2</i> spectroheliograms, 18-foot focus	1,220
K prominences, 18-foot focus . . .	1,080

## SUNSPOT ACTIVITY

The magnetic classification and study of sunspots have been continued by Nicholson and Mrs. Mulders. During the calendar year 1944, sunspot activity continued to decrease. Observations were made on 320 days; 123 days were without spots, as compared with 46 in 1943. In the new cycle, the number of groups increased from 6 in 1943 to 52 in 1944: the number in the northern hemisphere increased from 0 to 19; in the southern hemisphere, from 6 to 33. In the waning cycle, the number decreased from 89 in 1943 to 20 in 1944: the number in the northern hemisphere decreased from 54 to 8; in the southern hemisphere from 35 to 12.

The monthly means of the number of groups observed daily during the past two and one-half years are given in the accompanying table. A curve of these monthly means smoothed by overlapping three months' means indicates that the sunspot minimum occurred about 1944.3. The minimum in 1933 was lower than that in 1944. The total number of spots has increased more rapidly since the minimum in 1944 than in the corresponding interval after the minimum in 1933.

MONTH	DAILY NUMBER		
	1943	1944	1945
January . . . . .	1.1	0.3	2.5
February . . . . .	2.0	0.1	1.1
March . . . . .	2.4	1.1	1.9
April . . . . .	2.1	0.1	2.8
May . . . . .	1.8	0.2	3.6
June . . . . .	1.1	0.7	3.8
July . . . . .	1.3	0.6	...
August . . . . .	2.2	2.1	...
September . . . . .	0.9	1.1	...
October . . . . .	0.8	2.1	...
November . . . . .	1.3	1.3	...
December . . . . .	1.5	2.4	...
Yearly average . . . . .	1.5	1.0	...

## SUNSPOT POLARITIES

This new cycle is the fifth in which the magnetic fields in sunspots have been observed. The magnetic polarities of the spots of each new cycle have been arranged oppositely to those of the preceding cycle. "Regular" groups of the new cycle in the northern hemisphere are those in which the preceding spot has S (south-seeking) polarity and the following spot N polarity; in the southern hemisphere the polarities are reversed.

Magnetic polarities in each spot group have, so far as possible, been observed at least once. The classification of groups observed between July 1, 1944 and June 30, 1945 is indicated in the table on the following page.

One of the most fundamental facts concerning the nature of sunspots is the change in their magnetic polarity with the new cycle. It cannot be said, however, that all spot groups have the new polarity, for about 2.5 per cent conform to the polarity of the previous cycle. Such spot groups are classified as "irregular." A catalogue

HEMISPHERE	POLARITY					
	REGULAR		IRREGULAR		UNCLASSIFIED	
	Old cycle	New cycle	Old cycle	New cycle	Old cycle	New cycle
North.....	2	28	0	0	2	9
South.....	10	62	1	1	3	22
Whole sun.....	12	90	1	1	5	31

has been made by Richardson of all spot groups of irregular polarity observed at Mount Wilson since systematic magnetic records were begun in 1917. The only mention of irregular spot groups in the literature is that they are "small unstable groups." Careful study fails to confirm this rather casual characterization. On the contrary, the irregular spot groups are fully as large and stable as the regular spots. In fact, several irregular groups have been naked-eye objects which endured for two and three revolutions.

In addition to the statistical study, intensive investigation was made of a large, stable irregular spot which appeared recently in the southern hemisphere. This spot reached naked-eye proportions and endured for a second revolution. Photographs were taken for Zeeman effect in and far outside the spot; also for Evershed effect, Wilson effect, and direction of hydrogen vortex. The only unusual feature was that the direction of the hydrogen vortex was distinctly opposite to that prevailing in the southern hemisphere. Too much significance should not be attached to this circumstance, since about 20 per cent of all observable whirls fail to conform.

The present preliminary results indicate that the only irregular feature about "irregular" spots is their polarity. As a possible explanation, it is suggested that a solar cycle never completely dies out, but

consists of alternate strong and very weak cycles, the weak cycle corresponding to the so-called irregular groups. That is, if the number of spots all of the same polarity were plotted for three cycles, the shape of the curve would consist of two large humps with a small one between of amplitude about 2.5 per cent of those on either side. In this sense, the irregular spots are really not "irregular" at all, but merely a feeble manifestation of the previous strong disturbance.

#### PROMINENCES

Although the minimum of prominence activity which accompanied the sunspot minimum during the year reduced considerably the opportunity for prominence study, several phenomena of importance have been observed by Pettit.

An eruptive prominence was photographed on July 2, 1944, which moved to a distance of 355,000 km from the chromosphere along a trajectory whose apparent angle with the extended solar radius was  $51^\circ$ , one of the three highest inclinations observed in the catalogue of 68 eruptive prominences. Eruptive prominences are seldom seen near sunspot minimum. One other was observed at the present minimum (April 16, 1944) and one each at three previous minima.

A large interactive prominence extending over  $60^\circ$  of the solar limb appeared

at the beginning of January 1945. This was remarkable for being the first known instance in which a coronal cloud over a sunspot group took a direct part in an interactive prominence group. In previous cases material from the cloud had rained downward into the sunspot exclusively, but in this case a neighboring prominence drew the material to it with velocities increasing from 18 to 61 km/sec along a trajectory nearly parallel to the chromosphere.

#### GENERAL MAGNETIC FIELD OF THE SUN

Poor observing conditions have prevented some of the observing planned for the investigation of the general magnetic field, but one series of 28 plates in the green region has been obtained with the Lummer plate.

#### INFRARED SOLAR SPECTRUM

Final identifications and excitation potentials, now being added by Mrs. Sitterly to the principal table of infrared data, prepared at Mount Wilson by Babcock, make this table nearly ready for publication. Additions made at Mount Wilson during the year include: (1) numerous classifications of weak lines according to origin, whether solar or terrestrial; (2) further

instrumental checking and calibration of the visually estimated intensities of solar lines. Over a wide range of spectrum the estimates have required but small systematic corrections, and their accidental deviations from uniformity average only about 1 intensity unit.

#### ULTRAVIOLET SOLAR SPECTRUM

Measurements by Babcock show that, in the main, the scale of ultraviolet wave lengths given in the Revised Rowland Table requires systematic corrections of only 0.001 or 0.002 Å to fit it to the present International scale. Below  $\lambda 3100$ , however, the individual errors become greater, and Rowland's intensities are in some cases obviously wrong. The wave-length scale between  $\lambda 3133$  and  $\lambda 2995$  has been re-determined by reference to adopted standards in the blue region, and about 525 lines between  $\lambda 3060$  and  $\lambda 2950$  have been measured in the usual way. Twenty-five additional lines and other features of the spectrum were observed between  $\lambda 2950$  and  $\lambda 2914$ ; these have been roughly measured with a scale and magnifier.

Estimates of intensity are consistent with laboratory data, and identifications are well advanced. As would be expected, singly ionized elements become more prominent than in the visible spectrum.

#### LUNAR AND PLANETARY INVESTIGATIONS

##### CO-ALBEDO OF THE MOON

The albedo,  $A$ , of a planet has been defined as the ratio of the whole of the reflected light to the whole of the incident light. A similar definition applies to the ratio of the whole of the planetary heat emitted to the whole of the incident solar radiation; and, if  $A$  is measured radiometrically, this quantity is  $1 - A$  and is called the co-albedo. A calculation of  $1 - A$  by Pettit shows that the magnitude

of the planetary heat from the full moon outside the atmosphere is  $-15.63$ , a value 0.4 mag. numerically smaller than that obtained by direct measurement of planetary heat. Of this discrepancy, 0.26 mag. is accounted for by a re-discussion of the calibrations and the reductions to no atmosphere. The co-albedo of the moon from the corrected measures of planetary heat is 0.93, and from the calculations of  $1 - A$  it is 0.90.

### PLUTO AND JUPITER'S NINTH SATELLITE

Several photographic observations of Pluto and the ninth satellite of Jupiter have been made by Nicholson with the

60-inch telescope. With the assistance of Miss Richmond the positions of both objects have been measured and the results published.

## STELLAR INVESTIGATIONS

### PARALLAXES AND PROPER MOTIONS

Measurements of nine additional parallax fields, mainly of faint stars with large proper motion, have been completed by van Maanen. The most interesting of these is Ross 882, which, like the companion of Lalande 21258, appears to be a variable of very faint absolute magnitude. With a normal photographic magnitude of 13.1 to 13.3, it appeared of magnitude 11.8 on two photographs taken on March 11, 1943. Its absolute magnitude, based upon a measured parallax of 0''.146, has a minimum range of from +14.1 to +12.6. Its spectral type as determined by Joy is M4e. A negative parallax was found for the Wolf-Rayet star C. du C. +16°516, which has a radial velocity of +195 km/sec.

Five pairs of plates covering 0.8 square degree in the center of the Pleiades cluster, taken at the 80-foot focus of the 60-inch telescope and separated by an interval of about 25 years, have been measured by van Maanen. Of the 452 stars measured, 71 are found from their proper motions to be probable members of the cluster. Nine others with motions of the same order are probably not members. One star of photographic magnitude 15.6 has a motion which indicates that it may be a member of the Hyades.

### COLOR PHOTOMETRY AND STANDARD MAGNITUDES

Searles and Miss Joyner have seen through the press three of the four investigations reported last year. Before the revised color indices of standard polar

stars were printed, the results were extended to include all the useful data now available. Other investigations are:

(1) Reduction of the Cape basic magnitudes by Stoy to the International system. These standards, of high internal accuracy, in the Harvard Regions at declination  $-45^{\circ}$ , were connected with the north polar standards through Cape and Mount Wilson observations of the southern comparison stars for Eros. The Mount Wilson data, obtained in 1930 for another purpose, have rather large accidental errors; but the magnitude scales and the mean zero points are in close agreement with Yerkes measures of the Eros stars. Further, the color indices are independent of magnitude, and the zero-point correction to the spectrum-color relation is only 0.03 mag. Similar tests applied to the Cape magnitudes also show a very satisfactory accordance. As a final check, the Eros stars should again be compared with the Pole, although it is believed that the present reduction is close to the truth. All together, the results provide a photometric connection of the two hemispheres that should meet modern requirements.

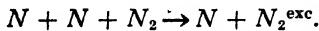
(2) In certain problems the squares of the errors of measurement appear in the coefficients of the normal equations. These terms do not cancel out, and when the percentage error is large, they affect seriously the solution for the unknowns. The method of removing this regression effect already reported for the case of a single unknown has been generalized to include any number of unknowns.

(3) The difference in scale for the color temperatures of stars derived from the In-

ternational color indices and from the C<sub>1</sub> and C<sub>2</sub> series of Stebbins and Whitford found in an earlier investigation was attributed to departures from black-body radiation. Proof is now available, with an indication that hydrogen-continuum absorption is chiefly responsible. Approximate corrections for the absorption, which it is hoped may be improved later, bring the scales into good agreement. With the zero point fixed at 11,000° for A5 stars, the color temperature for giant K<sub>0</sub> (HD system) is 3800° and for A<sub>0</sub> 15,000°–16,000°. These results are derived from the spectral interval 3400–5900 Å.

#### PHOTOELECTRIC PHOTOMETRY

The strong infrared radiation in the night sky detected several years ago by Stebbins and Whitford has been shown by Swings to be caused by molecular nitrogen. The wave length of 10440 Å, determined by measures with suitable filters, agrees with that of the (0,0) band of the first positive group of nitrogen. The absence of other N<sub>2</sub> bands suggests that emission of the (0,0) band involves conversion of the energy of dissociation  $D(N_2)$  into excitation in a three-body collision



Stebbins has completed the photoelectric measurements of 238 stars of different spectral types in six regions of the spectrum from  $\lambda 3500$  to  $\lambda 10000$ , and the results are ready for publication. The early-type stars from O to B<sub>3</sub> show small dispersion in intrinsic color, but many are strongly affected by space reddening. A dozen late-type giants in low galactic latitudes are also affected by such reddening. The most marked effect of absolute magnitude is near spectrum K<sub>0</sub>, where the colors of dwarfs, ordinary giants, and supergiants are all different.

The distribution of the radiation of different stars over the large range of wave lengths agrees with the distribution for a black body at suitable temperatures, but until a zero point of the temperature scale has been fixed, such so-called color temperatures must be relative. The determination of absolute stellar temperatures based upon a standard terrestrial source still remains one of the important problems of astronomy.

The colors of most of the stars fit into a uniform series. One of the few anomalous cases is that of the bright stars of the Trapezium cluster of the Orion nebula, where the previous result of Baade and Minkowski is confirmed, namely, that the optical properties of the absorbing interstellar material are modified to cause the Trapezium stars to stand out from a larger cluster in that region.

Comparison of the new colors with the International colors and the previous photoelectric colors of the North Polar Sequence give the ratios of the scales of color index. These ratios depend upon whether change of color is caused by change of spectral type or by change in the amount of space reddening for different stars.

#### VISUAL MAGNITUDES OF DOUBLE STARS

The measurement of the magnitudes of systems containing a bright star with a companion fainter than 11.0 was begun by Petit in December 1944. The wedge photometer was adapted to the Cassegrain focus of the 60-inch reflector, where a magnification of 746 was obtained. A high-speed sector was used to reduce the light of the bright star, and, in combination with the shade glasses of the artificial star and the wedge, provided a range of 9 magnitudes in the instrument.

Systems in which the separation is less

than 3 seconds were given special attention, many measures being made on doubles of slightly less than 1 second of arc separation. This work is limited to periods of good seeing, but even with this handicap 94 double-star measures were obtained, many of which include two sets of determinations.

#### VISUAL MAGNITUDE OF NOVA PUPPIS

Nova Puppis was measured by Pettit on 36 nights between October 15, 1944 and

April 19, 1945. There was little net change in magnitude over this period. The mean magnitude October to January was 9.97, and January to April, 10.00.

#### VISUAL MAGNITUDE OF $\alpha$ ORIONIS

This star is passing through a minimum of light. Measures on 19 nights from February 21 to April 16, inclusive, give a mean magnitude of 1.15, which is just within the range usually given, 0.1 to 1.2 magnitudes.

### STELLAR SPECTROSCOPY

#### TAURUS CLUSTER

Since the 1943 report, 159 spectrograms of 120 stars in the region of the Taurus cluster have been obtained and measured by R. E. Wilson. Sixteen of these stars had not been previously observed. Radial velocities have now been determined for 239 stars in this region. All but 10 of the velocities are based upon more than one spectrogram. Of the stars observed, 157 are probably cluster members, 26 are doubtful, and the remainder definitely do not belong to the cluster. The survey covering all suggested cluster members brighter than 10.5 visual magnitude will be completed with the reobservation of some 25 stars during the latter half of this year.

#### DWARF STARS

Spectrographic observations of 140 stars with proper motions greater than 0''.35 have been completed by Joy, and the radial velocities, spectral types, and spectroscopic absolute magnitudes will soon be ready for publication. About 40 dwarf M-type stars having emission lines of hydrogen and calcium (H and K) have been listed and observed spectroscopically. The radial velocities have been measured and studies of the spectra are under way. These

stars are among the faintest known as regards intrinsic luminosity.

#### RADIAL VELOCITY OF RIGEL

Further observations by Sanford show that although the radial velocity of Rigel ( $\beta$  Orionis) undoubtedly varies, no definite period seems to exist. The possibility of a period of less than one day, though not ruled out, seems unlikely. Velocities derived from the hydrogen and helium lines differ systematically from those of other lines. In some respects there seems to be a similarity in behavior between this star and  $\alpha$  Cygni.

#### RADIAL VELOCITY OF $\alpha$ ORIONIS

The recent minimum of light of  $\alpha$  Orionis has afforded an opportunity to examine possible changes of spectrum with phase. Several spectrograms taken by Adams with the 114-inch camera of the coudé spectrograph show no striking differences from the spectrum at maximum, but some interesting changes in detail. Changes are especially marked in such lines as those of  $Mn\,i$  and  $Cr\,i$ , which arise from the zero level of excitation. These lines appear as relatively sharp components superposed upon broad hazy

lines which seem to shift back and forth beneath them. The sharp components show no variation in radial velocity over a period of eight years, whereas the diffuse lines show a range of about 8 km/sec. With lower dispersion the lines would blend and an intermediate value would be observed. This may account for the somewhat discordant results found by different observers for this star and a few others of supergiant M type.

#### VARIABLE STARS

Studies of the spectra of numerous classes of variable stars have been made by the stellar spectroscopic observers. These have included long-period variables of spectral types M and N, Cepheids, a few short-period variables, and stars of the T Tauri and SS Cygni classes of variability. Some of the stars had been investigated previously but have now been reobserved with higher dispersion.

The results of a comprehensive study by Joy of the spectroscopic behavior of a group of 11 variable stars resembling T Tauri in many respects have been collected and prepared for publication. The physical properties of these stars suggest that they may form a new class characterized by irregular light-variations of three magnitudes or more, spectral types of dF<sub>5</sub> to dG<sub>5</sub> with emission lines resembling the upper solar chromosphere, and association with dark or bright nebulosity.

Observations for determining the period and radial-velocity curve of the SS Cygni-type variable AE Aquarii have been continued. The velocity changes appear to be regular with a period of approximately 0.7 day. The shape and intensities of the bright lines show considerable variation.

During the past two years Merrill has obtained about 80 spectrograms of long-period variable stars with the coudé spectrograph (dispersion 10 Å/mm). A num-

ber of these plates, taken when the variable was relatively faint, required long exposure. More than half the plates, many of which extend far into the ultraviolet and record a large number of lines, have been measured, and a beginning has been made on the reduction and discussion.

The curious multiple structure of the bright hydrogen lines in the spectra of certain red variable stars has puzzled astronomers for many years. New evidence that the minima in some of the lines correspond to dark lines of the reversing layer was supplied by a comparison of spectrograms of  $\sigma$  Ceti, dispersion 3 Å/mm, taken near the maximum of January 1945, with one of  $\beta$  Pegasi, a non-emission M-type star whose absorption-line spectrum is much like that of  $\sigma$  Ceti. The close correspondence of details in several bright lines, particularly in  $H\theta$  and  $H\iota$ , with similar details at the same wave lengths in the spectrum of  $\beta$  Pegasi seems convincing. Six or eight minima within the bright lines  $H\zeta$ ,  $H\eta$ ,  $H\theta$ , and  $H\iota$  have been identified with metallic lines. The conclusion is that the minima which cause the bright lines to appear multiple are just a part of the normal dark-line spectrum, and that the hydrogen series is emitted as single, slightly widened lines at a level *below* the stratum of absorbing metallic gases. This is an unusual inversion.

A series of six spectrograms of the short-period variable star RR Lyrae well distributed in phase has been obtained by Sanford with the coudé spectrograph. The spectrograms taken at maximum and minimum of light show that the amplitude of the radial-velocity variation given by the hydrogen lines is about 30 per cent, and that by the H and K lines about 60 per cent, larger than that given by other lines in the spectrum. These results confirm those obtained previously with lower dispersion.

### B-TYPE STARS

Merrill has observed at intervals with the coudé spectrograph certain Be-type stars with spectral lines which show anomalous displacements, and Sanford has devoted considerable time to observations of B-type stars in open clusters.

Mr. W. C. Miller, in addition to making many instrumental tests of the 10-inch telescope, has obtained a number of excellent objective-prism spectrograms on which numerous bright-line objects, some previously unknown, are present. He has also obtained slit spectrograms of Be stars and other objects with the 60-inch telescope.

### CN BANDS IN N- AND R-TYPE STARS

An examination by Sanford of "carbon" stars of types N and R shows that in the cooler N-type stars the CN bands are weak in the violet part of the spectrum and strong in the red, whereas in the hotter R-type stars the reverse is true. The N star Y Canum Venaticorum, for example, shows no violet CN spectrum, but very strong bands in the red. The laboratory investigations of CN bands by Dr. King and the theoretical study of the absorption transition probabilities by Dr. Swings afford an adequate explanation of the stellar results.

### PECULIAR STARS AND NOVAE

A cooperative study by Joy and Dr. Swings has led to numerous very interesting identifications of lines in the spectrum of RS Ophiuchi at the time of the appearance of the coronal lines. These include a strong line at  $\lambda 6827$  due to [Kr III]; a line at  $\lambda 6914$  due to [A xi] and one at  $\lambda 5536$  of [A x]; and several lines due to [Fe VII], [Fe VI], [K IV], [Ca VII], [V VIII], and other elements. This is the first identification of krypton in celestial spectra, and of forbidden argon xi in any object.

A similar investigation by Sanford and Dr. Swings has led to the following identifications in Nova Puppis in the region  $\lambda 4585$ – $\lambda 8600$ : C IV, N V, O I, Si I, Si II, [K IV], [Ca VII], Fe II, [Fe VI], [Fe VII], and possible identifications of N IV, [Mn VI], [Fe X], and [Fe XI].

On April 3, 1945 the recurring nova T Pyxidis, which had maxima in 1890, 1902, and 1920, was found by Joy to be three magnitudes brighter than normally. Spectrograms indicated that the star had passed the maximum of an outburst several months previously. The spectrum was typical of novae at a late phase. The emission lines were much wider than those of Nova Puppis 1942 or of the well known recurring nova RS Ophiuchi. Of especial interest is the identification in T Pyxidis of the coronal lines  $\lambda 5303$  [Fe XIV] and  $\lambda 6374$  [Fe X], the former being the stronger of the two. Other identified lines of high excitation are those of N III, [Ne III], [Ne IV], [O III], [Fe V], [Fe VI], and [Fe VII].

In the course of his examination of peculiar spectra, Dr. Swings has identified several lines in P Cygni with those of O I and C II, and a line on Lick Observatory spectrograms of  $\eta$  Carinae as the principal forbidden line of Cr II. An emission line at  $\lambda 7155.1$  found by Merrill in  $\nu$  Sagittarii is identified as a low-level [Fe II] transition. From a study of high-dispersion spectrograms of  $\beta$  Coronae Borealis which extend to  $\lambda 3100$ , Dr. Swings concludes that no lines due to neutral or doubly ionized rare earths are present, although lines of the singly ionized earths are prominent.

### INTERSTELLAR LINES

The investigation of complex interstellar H and K lines in the brighter O- and B-type spectra has been continued by Adams,

and about 250 stars have been observed in the second order of the coudé spectrograph on a scale of 2.9 Å/mm. The lower dispersion of the 32-inch Schmidt camera has been used for stars fainter than magnitude 6.5. The most interesting result found is the rapid motion of some of the inter-

stellar clouds in Sagittarius and Cygnus, amounting in some cases to as much as 60 km/sec.

Photographs of the interstellar D lines in the spectra of a few bright stars have been obtained by Merrill with the coudé spectrograph on a scale of 6 Å/mm.

## GALACTIC NEBULAE AND NOVAE

### DIRECT PHOTOGRAPHY

Among direct photographs obtained by Dr. Duncan with the 100-inch telescope are two of the Trifid nebula, and one each of the diffuse nebula NGC 6357, the planetary nebula NGC 7293, and the dark nebula Barnard 86 Sagittarii. Photographs with the 60-inch telescope include those of diffuse nebulae M 8, M 16, and M 17. Some star clusters and the short-period variable star CY Aquarii were also observed. The photographs of the Trifid nebula and the 86 Sagittarii nebula were compared with similar photographs made by Dr. Duncan in 1921, but no change in the nebulae or the neighboring stars was detected.

### SPECTRA OF PLANETARY NEBULAE

The survey of objects on objective-prism photographs which show  $H\alpha$  in emission with little or no continuous spectrum has been continued by Minkowski. Of 82 such objects investigated, only 8 have been found to be Be stars. Most of them are nebulae, 50 being planetaries and 15 diffuse nebulae. The remaining 9 objects are stars of peculiar types.

The investigation of the spectra of these objects is still in progress, and it is too early to summarize the results. Some planetaries have been found which show only the  $H$  lines together with mere traces of forbidden lines. The relative intensity of the  $[N\,II]$  lines varies widely; even in nebulae which are similar in other respects, they may be the strongest lines

in the spectrum or negligibly faint. Such intensity variations may have to be explained by variable nitrogen content.

Many of the planetaries are very strongly reddened by space absorption. A systematic survey, which can readily be extended to limits fainter than that of the available objective-prism plates, should permit investigation both of space absorption at large distances and of the galactic distribution of planetary nebulae. Of the 9 peculiar stars, 3 are of type B with strong  $Fe\,II$  lines, 1 being a close duplicate of  $\eta$  Carinae. The other 6 are M-type stars with emission lines of high ionization, 1 showing strong lines of  $[Fe\,VI]$  and  $[Fe\,VII]$ . In all these stars  $H\alpha$  has very high relative intensity; this explains the relatively large number of peculiar stars included in the material.

### COLORS OF FAINT CEPHEIDS IN THE CYGNUS CLOUD

The photovisual scale in Selected Area 40, which had previously been used for inter-comparison of four distant Cepheids in the Cygnus cloud, has been established more accurately by an entirely new determination of both scale and zero point undertaken by Baade in cooperation with Dr. Seares. To determine the absorption beyond 10 kpc in the Cygnus cloud, nebular counts were made on a series of 1-hour exposures taken at the 100-inch telescope. The area investigated on these plates is a narrow strip at longitude  $41^\circ$  between latitudes  $+4^\circ$  and  $+15^\circ$ .

## SHELL AROUND NOVA HERCULIS

The shell of this nova, which has been observed photographically by Baade at the Cassegrain focus of the 100-inch telescope, has continued its steady decrease in brightness. The decrease is especially marked in the emissions of  $\lambda 4959$  and  $\lambda 5007$  of [O III]. Interesting structural changes have taken place in the shell images of the [N II] lines  $\lambda 6548$  and  $\lambda 6584$  and the [O II] lines at  $\lambda 3727$ . The strong [N II] emission along the minor axis of the shell has broken up into three distinct

condensations, two at the ends of the minor axis and one at its center. In the [O II] image, which until 1944 presented the appearance of an amorphous elliptical disk, the ring structure suddenly emerged between 1944 and 1945. The [O II] ring has two gaps at the ends of the minor axis where the strong [N II] condensations are located. Since the same gaps occur in the [O III] ring, it would appear that forbidden oxygen emissions are suppressed where the [N II] emissions are unusually strong.

## EXTRAGALACTIC NEBULAE

The successful resolution of the inner part of the Andromeda nebula and of the early-type members of the local group of galaxies mentioned briefly in the last report has brought within our grasp the solution of a number of important problems. The technical difficulties encountered in precise observations of this sort are many, since the optical power of the 100-inch telescope has to be utilized to its extreme limits. Progress should be easier in the near future, however, because of certain new photographic emulsions now being developed at the Eastman Kodak Research Laboratories through the generous cooperation of Dr. Mees. The new plates are sensitized for a region of the near infrared which is free from strong night-sky emissions. Thus far, an increase in speed by a factor of 2 over the emulsions previously used has been achieved, but there is good reason to expect that a gain of a full magnitude will be realized before long. Several nights in the spring of 1945 were devoted by Baade to tests of the experimental emulsions sent by the Eastman Research Laboratory.

During the year under review, the main part of the program was a search for long-period variables in other members of the local group. If the recently derived

absolute magnitudes of these variables are not seriously in error, they should be observable (at least those with periods shorter than 200 days) with the present technique. So far the search has been restricted to M 32 and NGC 205. In both, a considerable number of faint variables have been found. Observations in the next two seasons should make it possible to decide whether these stars are the elusive long-period variables.

Nights on which the definition was not sufficiently good for the resolution of M 32 and NGC 205 were used for a search for emission nebulae in M 31. Emission patches in M 31, which were first noted on red exposures taken in 1944, present a problem. Invisible on ordinary blue-sensitive plates, they are outstanding features when photographed in  $H\alpha$  light; they range in size from giants about 100 parsecs in diameter to small specks just distinguishable from stars. Only a spectroscopic investigation can decide whether their weakness in the blue is caused by selective absorption alone, or whether some other factor is involved. In any event, the generally accepted statement that emission patches are a common feature only in late-type spirals and irregular systems needs radical revision.

### CEPHEIDS IN THE 'SEXTANS' SYSTEM

The investigation of the Cepheids in this important dwarf system has been continued by Baade. Because the nebula can be observed only during the unfavorable winter months, the necessary plates are being accumulated very slowly.

### NEBULAR VELOCITIES

Velocities of 63 extragalactic nebulae have been observed and measured by Humason during the year. The number of extragalactic nebulae with velocities de-

termined at Mount Wilson now totals 433. It is hoped that this number can be increased to 500 during the coming year, after which time the results will be published and discussed.

A redetermination of the radial velocities of the members of the local group of galaxies, with the highest possible dispersion for each object, is under way. Preliminary solutions with the data already available indicate that the new velocities will furnish a well determined value of the galactic rotation.

## LABORATORY INVESTIGATIONS

### NIGHT-SKY RADIATION

A brief reference has already been made to the identification by Dr. Swings of the intense infrared radiation in the night sky observed by Stebbins and Whitford. The radiation is the (0,0) band of the first positive system of  $N_2$ . Failure to observe other strong  $N_2$  bands indicates a mechanism which enhances the (0,0) band relatively to the other vibrational transitions. Such a mechanism has been suggested by Dr. Swings, in which during the night  $N_2$  molecules are brought into the zero vibrational level through three-body recombinations. The presence of a fairly large number of nitrogen atoms in the upper atmosphere is implied.

### VIOLET AND RED BANDS OF CN

Reference was made in last year's report to the laboratory investigations by Dr. A. S. King of the relative intensities of the CN bands. Dr. Swings has studied the ratio of the absorption transition probabilities between the violet and the red systems, and obtains an estimated ratio of 87 to 1. This would explain the weakness of the red system in absorption in the laboratory.

Some astrophysical conclusions are that red bands of CN should not be expected in cometary spectra; that no line of the red system should appear in interstellar absorption; and that in carbon stars with weak violet bands of CN there is less continuous absorption in the red than in the violet.

## MAINTENANCE AND OPERATION

During the year, as in the past three years, the work of the instrument shop has been very largely upon apparatus for military use. About 16 per cent of its time has been given to Observatory work, mainly for maintenance and repairs. Very little new equipment has been added. In the optical shop and the department of

design and drafting the situation has been similar to that in the instrument shop.

Albert McIntire has been in charge of the instrument shop, Donald O. Hendrix of the optical shop, and Edgar C. Nichols has carried out the design of nearly all the apparatus which has been constructed. These three departments of the Observa-

tory have had to meet the problems of a great variety of instruments of difficult design and frequently of unusually high precision, and have been most successful in solving them.

On Mount Wilson, A. N. Beebe, superintendent of construction, has carried on necessary repairs and has cared for the difficulties of transportation during the

winter months. He has also provided for such construction in Pasadena as has been required by the government work in progress. Kenneth de Huff, engineer, has maintained the extensive equipment on Mount Wilson necessary to the operation of the instruments, and in addition has been able to give considerable time to work in the instrument shop.

### THE LIBRARY

During the past year the library has added 299 volumes, making a total of 15,608 in the collection. Of the volumes acquired, a large proportion are from Dr. Hale's library, described in last year's report; 48 volumes were purchased; but only 47 were bound because of difficult conditions at the bindery due to the war. The

number of periodicals and serials received is still small; 27 of these are gifts or exchanges, including publications from several research organizations in Sweden and Switzerland. Distribution of the Observatory publications (since 1942 sent only to the Americas) will be resumed when conditions permit.

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## GEOPHYSICAL LABORATORY

*Washington, District of Columbia*

**L. H. ADAMS, Director**

During the year ending June 1945 the Geophysical Laboratory has continued in essentially the same program of war work that was carried forward during the preceding three years. One government contract under the auspices of the National Defense Research Committee was brought to a conclusion, except for final report writing, at the end of June; but the work under a larger contract had not diminished in volume on that date. Two additional members of the regular scientific staff were given leaves of absence without pay for the purpose of taking positions with war agencies, but as before a considerable number of persons employed on a temporary basis have supplemented the efforts of the regular staff in carrying out the various investigations, the results of which have found specific application to military needs. Closely related to the work under NDRC supervision have been a variety of services performed directly for the Army and the Navy.

It has not yet been deemed practicable to resume any considerable part of our normal activities. Upon request from the Division

of Geology and Geography of the National Research Council, however, one of our staff members made a brief trip to the newly formed volcano Parícutin in Mexico for the purpose of obtaining firsthand knowledge of that volcano and of being thereby enabled to advise the National Research Council group that had been set up to coordinate the volcano studies.

At the time this report was written, it became evident that the experimental work for NDRC at the Geophysical Laboratory could properly terminate in October, and that the additional obligations to that agency in connection with its final reporting would be fulfilled by the end of January; after which the Laboratory will be in a position to turn its attention again toward fundamental research in earth sciences. Comprehensive plans will be made for a future program; also, at an early date, unpublished results of studies interrupted in 1941 will be assembled. During the past year, it was found possible to prepare one short paper (described below) for presentation at a scientific meeting and subsequent publication.

### SUMMARY OF PUBLISHED WORK

(1083) Relations of lamellae and crystallography of quartz and fabric directions in some deformed rocks. Earl Ingerson and O. F. Tuttle. *Amer. Geophys. Union, Trans.* 1945, pt. I, pp. 95-105 (1945).

Measurements of quartz lamellae in metamorphic rocks of the Washington, D. C., area and new measurements from the Ajibik quartzite confirm previous generalizations as to the relations of the lamellae to the c-axis of quartz and to the fabric axes of the rocks.

A more detailed statistical study than has been made previously yields interesting and significant results. This study is carried out by dividing each fabric diagram of lamellae into four zones according to the angles that the c-axes of the quartz make with the B fabric axis, and tabulating measurements for each zone.

The tabulations show that the lamellae are not controlled by definite crystallographic planes or zones in the quartz structure. They

are apparently controlled almost entirely by the stress pattern which determined the (quartz) fabric axes for the rock. Since the orientation of the c-axes is also at least in part controlled by this pattern, there is an indirect relation between lamellae and the structure of the quartz.

Lamellae can be important in geologic interpretation in determining not only the B-axis, but also direction of motion, if the lamellae and c-axes of the same grains are

plotted. Lamellae can also serve in certain cases as an index of intensity of deformation.

(1084) Annual Report for 1944-1945.

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## DEPARTMENT OF TERRESTRIAL MAGNETISM

*Washington, District of Columbia*

JOHN A. FLEMING, *Director*

### SUMMARY

The long-sustained effort required for waging a war of world-wide extent continued unabated through the report-year (July 1, 1944, to June 30, 1945) and rendered impossible the execution of anything like the normal program of the Department of Terrestrial Magnetism. Military and naval operations have greatly interfered with geophysical investigations requiring international cooperation, of which terrestrial magnetism and electricity are good examples. It has not been possible to equip expeditions for field-work in foreign lands and on the oceans, to provide the much needed data for secular-variation studies. Nevertheless, although practically all of the Department's staff have turned attention to the solution of problems connected with the war, considerable progress has been made along certain lines. Moreover, much important work, the results of which are not yet publishable, has been brought to a successful conclusion.

Operations relating to national defense continued to make use of observational, theoretical, and instrumental material, and of experience of members of our staff, accumulated during more than forty years. These have involved since August 1940, under thirty individual contracts (at actual cost and without overhead charge) with the Office of Scientific Research and Development, National Defense Research Committee, various bureaus in the Army and the Navy, and the Maritime Commission, a total expenditure of slightly over \$2,006,000. The Institution has contributed services of its regular scientific personnel in the Department, an aggregate compen-

sation amounting to something over \$478,500, in addition to use, without charge, of laboratories, scientific equipment, machine-tools, and site. On July 1, 1945, obligations with the War and Navy Departments and the Maritime Commission were still in effect, involving work of high postwar priority. It may be sometime in 1946, therefore, before all contracts are completed and the full normal program of research can be resumed.

The contractual obligations required over 90 per cent of the services of the available full-time and part-time regular staff of 81 in Washington and at the observatories. One hundred and fifty-four temporary employees (including physicists, engineers, mathematicians, computers, machinists, clerks, and guards) were necessary, and the peak number of persons at the Department during the year was thus 235. Besides these, 12 of our regular and 2 of our temporary personnel were on leave of absence either in the armed services or in governmental war agencies; of these, 1 returned to duty at the Department on January 1, 1945. Many of the temporary personnel were again made available by various universities and individual organizations through generous granting of leaves of absence.

### REVIEW OF YEAR'S ACTIVITIES

*Geomagnetic investigations.* The voluminous tables required to correct magnetic observations for secular changes, for the natural magnetic variations and disturbances, and for cosmic variations were

extended to include the year 1944. The reductions of field-observations to the four epochs 1912.5, 1922.5, 1932.5, and 1942.5 were completed for over 10,000 stations on land and sea. Isoporic charts of the world for declination and horizontal intensity for these four epochs were completed, and others for the five remaining elements or components were well under way. Forty-five isomagnetic charts of the declination and horizontal and vertical intensities with indications of anomalies were completed for the area of the western Pacific and were printed. Further useful tests for adjusting isomagnetic charts to mutual consistency were evolved.

Calculations were made for continuation of magnetic fields on a plane or a sphere to adjacent regions of space.

Isolines of equal daily and hourly percentage-frequency of occurrence of visually observed aurora were mapped for the Southern Hemisphere. The extent and frequency of expansions of the auroral zone during magnetic storms are being studied, using geomagnetic as well as auroral data.

*Cosmic relations.* Further analyses of cosmic data were made with regard to solar, geomagnetic, ionospheric, and auroral correlations. The operational value of previous conclusions regarding the effects of ionospheric and geomagnetic disturbances on conditions of radio transmission and reception was confirmed.

Provision for the maintenance and operation of the recording cosmic-ray meters at Cheltenham (Maryland), Huancayo (Peru), Godhavn (Greenland), Christchurch (New Zealand), and Teoloyucan (Mexico) was continued, with only minor interruptions, in spite of difficulties occasioned by the war. Analyses of the resulting data must await return of personnel from war activity. By

1949 the records will include at least a complete sunspot-cycle for all five stations —ample for statistical analyses concerning seasonal effects in different localities, solar-day and lunar-day variations, and geomagnetic and other possible correlations.

The Department continued to act as a clearing house for observations of sunspots by many observers of the American Association of Variable Star Observers, pending re-establishment of communication with the international center at Zürich, Switzerland.

*Terrestrial electricity.* Following some improvements in CIW ionization-meters, particular attention was directed to effects of secondary radiation, "volume-contamination," and "wall-contamination."

An important program was begun on adaptation of electronic circuits to atmospheric-electric instruments in place of electrometers. This has resulted in improvements in investigation of rapidly varying fields associated with thunderstorms and in observations under difficult operating conditions, for example, on airplanes in storm regions.

Tests showed that the diminution in the rate of ionization which occurs when people occupy a room is due to a diminution in the radon and thoron content of the air. It is not yet determined, however, why this occurs. Automatic records of rate of ionization, for investigation of diurnal-variation and annual changes, were obtained for almost the entire year. For equilibrium-conditions the alpha-ray ionization inside a room was found to be about double the gamma-ray ionization. This ratio is about 50 per cent greater than that obtained from estimates by Eve for outside air-conditions.

The small-ion content of the air was found to vary directly as the rate of ionization, becoming zero when the ionization

is zero. Results indicate that the recombination-coefficient between small and large ions may vary with the rate of ionization. The alpha-particle stopping power of cellophane was found to be much greater than that anticipated from calculation.

The probable error of a single observation in measurements of ion-content and air-conductivity at sea was determined, from analysis of results obtained during the last three cruises of the *Carnegie*, to be about 12 per cent. The average error for each instrument also appears to be systematic and of such a nature as to give too low a value for the element measured, perhaps not over 1 per cent in mean values.

Research on seasonal changes in the diurnal variation of earth-currents and the geomagnetic field from 12 years of record at Tucson (Arizona) was completed. The changes were found to be consistent with effects attributable to recognized current-systems in the ionosphere. Two anomalous features disclosed, in addition to the regular seasonal changes, were explained as probably due, the one to space-variation in the conductivity of the ionosphere, and the other to erratic shifts in the latitudes of current-centers.

*Ionosphere.* Activities of the Ionospheric Section were devoted almost exclusively to military applications. Additional important contributions to improvement in radio-communication circuits resulted from the continued accumulation of ionospheric data at Huancayo, Watheroo, and College, and the five other sites outside the continental United States. Arrangements were well under way by the end of June for two more strategically placed stations.

The active program of research and development and the instruction of observing teams were continued at the Kensington Laboratory and at several field-stations. These resulted in design and construction

of improved and simplified manually operated ionospheric equipment.

Seasonal features of sporadic-*E* already established for the Northern Hemisphere were confirmed for the Southern Hemisphere. Tests for recurrence-tendency with the 27-day period of solar rotation did not show positive correlation.

Further attention was devoted to post-war observational program and items of research (see Year Book No. 43). Most important are (1) completion of the program at Huancayo and Watheroo to cover a full sunspot-cycle, (2) extended analyses of accumulated data, and (3) new projects directed toward specific problems which promise positive solutions in a reasonable length of time.

*Nuclear physics.* The 60-inch cyclotron was in almost continuous daily operation, without any major breakdown and with few minor changes, and with almost automatic operation. A new ion-source was developed giving 80 to 90 hours of operation.

In the emergency the cyclotron was almost wholly used in bombardments for special researches of the Naval Medical Research Center and the United States Public Health Service. The research-program utilizing the cyclotron and the 5,000,000-volt static generator for nuclear physics must be postponed until sometime during 1946 to meet immediate post-war needs for radioactivated products for chemotherapeutic and similar research. Special bombardments were also made for the National Defense Research Committee, the National Bureau of Standards, and the Department of Agriculture.

A method was developed for making a stable colloidal preparation of metallic antimony which is free from other forms of antimony.

*Observatory- and field-work.* The complete geomagnetic, atmospheric-electric,

ionospheric, seismic, and meteorological programs were maintained at the Watheroo, Huancayo, and College magnetic observatories. Special studies relating to geomagnetic, atmospheric-electric, and ionospheric problems were made by the staffs at each observatory. The atmospheric-electric program in cooperation with the United States Coast and Geodetic Survey at its Tucson Magnetic Observatory was continued. The Department cooperated, through loan of instruments and otherwise, with eight observatories abroad.

Maintenance of international magnetic standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was effected through the Division of Geomagnetism and Seismology of the Survey.

Though no field-work other than that at the observatories could be undertaken, it was possible to assist various governments, through loans of magnetic instruments, in undertaking new magnetic surveys and obtaining repeat-observations at established stations.

*Miscellaneous.* The report-year included the fiftieth anniversary of the establishment of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. That journal was founded by Dr. L. A. Bauer, first Director of the Department, and has been conducted since 1932 by his successor.

In it have been published many of the original papers of members of our staff. It has been a potent factor in the promotion and diffusion of geomagnetic and geoelectric knowledge and progress, not only in the United States, but throughout the world as well.

The continued services of three of the retired staff—J. W. Green and W. F. Wallis during the whole year and A. Smith until December 29, 1944—have been most useful in the emergency.

Dr. Harry Marcus Weston Edmonds, who retired in 1930 after 20 years of activity in the Department, died in his eighty-second year at Berkeley, California, April 4, 1945. He was surgeon and magician of the *Carnegie* for several years, and in command of the vessel from December 1917 to June 1918. He did arduous field-work in Canada and constructed and equipped the Huancayo (Peru) Magnetic Observatory. He represented the Department in its cooperation at the Apia Observatory during part of the transition period after World War I. His record is one of unselfish devotion and high efficiency in a long life of scientific service.

Once more the necessarily brief detailed accounts in this report of our activities illustrate the team work and professional partnership so singularly necessary in the scientific provinces of the Department.

## INVESTIGATIONAL AND EXPERIMENTAL WORK

### TERRESTRIAL MAGNETISM

Those of the staff at Washington chiefly concerned with geomagnetic research were Fleming, J. W. Green, Hendrix, Johnston, Miss Lange, McNish, Scott, Sherman, Vestine, Wallis, and Wells, with Bernstein, Mrs. E. G. Crow, Davids, Shapley, and Zimmer (until his death February 5, 1945) of the temporary staff. McNish gave his full time to war problems related par-

ticularly to applications of geomagnetism. The others named gave the greater part of their time to matters related directly or indirectly to the war effort.

### GEOMAGNETIC ANOMALIES

Vestine and Davids developed analytical and computational procedures for the analysis and interpretation of geomagnetic

anomalies. These relate particularly to techniques of geophysical prospecting by magnetic and gravitational methods. Relations among the surface-components of field and their gradients were compiled, and techniques of analysis using models, Fourier series, Fourier-Bessel series, power series, and surface integrals described. These methods do not permit unique location of the sources of field from magnetic data alone, but under favorable conditions permit useful inferences regarding subsurface structure, of advantage in prospecting for certain minerals and petroleum. Application of the results to illustrative examples is being undertaken.

#### GEOMAGNETIC DISTURBANCES AND COSMIC RELATIONS

The geographic incidence of aurora and magnetic disturbance in the Southern Hemisphere was studied, using observations at about 40 auroral stations and 13 magnetic observatories. The position of the southern auroral zone was estimated from geomagnetic data and compared with the results of observations of aurora. Tentative isochasms were drawn for aurora observed in absence of cloud, results being corrected also for the influence of sunlight on observing conditions, and they appear closely to resemble corresponding isochasms for the Northern Hemisphere.

The geomagnetic disturbance daily variation ( $S_D$ ) was derived for stations in southern auroral regions. Little evidence was found of important differences in the average characteristics of geomagnetic disturbance as between south and north polar regions, but more observations are necessary, particularly at the auroral zone, where as yet no observatory has operated, before a definite conclusion can be reached.

Lines of equal average hourly percent-

age-frequency of aurora were mapped for the Northern Hemisphere for several positions of the Sun relative to the Earth. The region of highest average hourly percentage-frequency coincides with the region of most concentrated electric current-flow estimated for the average of 40 magnetic bays of the Polar Year 1932-1933.

Vestine and Miss Lange are deriving the average position of the northern auroral zone for the various years of the sunspot-cycle. The statistical frequencies of the magnitudes of daily departures of the auroral zone north and south from its average position are being compiled, using measurements of geomagnetic disturbance at stations in high latitudes.

#### PERMANENT FIELD

Davids and Bernstein continued studies and tests for ensuring greater mutual consistency among isomagnetic charts. Professor James H. Taylor, of George Washington University, completed theoretical examination of the problem of adjusting isomagnetic charts to mutual consistency, the definition of the normal geomagnetic field, and intrinsic properties of mapping contours.

Current compilations of magnitude of major short-period magnetic fluctuations have been made for results measured at Ivigtut (Greenland) and College (Alaska).

Tables are under construction to permit analysis and continuation of surface magnetic fields over a sphere, using the method of surface integrals previously reported.

At least 90 per cent of Vestine's time was spent on war contracts of the Department, with the Director's supervision and advice. The main activities may be listed as follows: (1) Continuation of work of the previous two years in supervising, with assistance of Miss Isabelle Lange, temporary professional and asso-

ciate workers. Many of these activities were along lines ordinarily normal to the investigations of the Department, so that this work remains of enduring value in time of peace. These activities were greatly facilitated by the cooperation and assistance of many others of the Department's staff, and especially by the following: Johnston and Scott, who generously gave of their time in providing geomagnetic data; Seaton, with Malich of the temporary staff, and Corp, who made measurements of geomagnetic fluctuations at College (Alaska) and Ivigtut (Greenland), respectively; and Harradon, who translated numerous foreign passages in publications and who together with Dove made available almost daily the geomagnetic data in the library. Green and Wallis made particularly val-

able revisions of data on land and sea, especially in preparing final summaries of data as corrected to International Magnetic Standard. Hendrix and Harrison, with Doeple of the temporary staff, drew the necessary graphs, maps, and diagrams, and Capello and Dove typed and prepared manuscripts.

Sherman, Scott, and Vestine installed a visually recording magnetograph in the field at Sterling, Virginia.

In supervision of work, Vestine and Miss Lange had the valuable assistance of the computing supervisors Cooper, Laporte, Meier, Saltarelli, J. W. Smith, and E. J. Snyder, of the temporary staff. Between 40 and 50 others contributed in temporary technical and computing capacities.

#### TERRESTRIAL ELECTRICITY

War research in the Section of Terrestrial Electricity continued on a slightly reduced scale from that of the three previous years. Nearly all of Sherman's time was spent on war projects. Torreson remained on leave of absence with the Applied Physics Laboratory of Johns Hopkins University for the Office of Scientific Research and Development and United States Navy through December 1944, and returned to the Department January 1, 1945. He then began editing, compiling, organizing, and preparing material relating to the atmospheric-electric work done at sea on the *Carnegie* in 1928 and 1929, for the volume Oceanography III in the series "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929." About one-quarter of Rooney's time was given to war research problems and the remainder to Section routine and research. Gish and Wait devoted most of their time to atmospheric-electric research but gave some time to consultations and investigations related to the war effort.

#### ATMOSPHERIC ELECTRICITY

*Development of instruments and methods.* Some minor modifications and improvements were made in the ionization-meters (Gish and Sherman) developed for the investigations of Professor V. F. Hess. Considerable study (Gish) was directed to the interpretation of the results obtained by Hess, with particular attention to the effects of secondary radiation, "volume-contamination," and "wall-contamination." The method of Hess involves the use of three ionization-chambers of identical shape but with different ratios of area to volume, so that the effects of wall-radiation can be segregated and eliminated from the measured values. Examination of the data obtained with the three chambers under different conditions with respect to the freshness of the nitrogen they contain, the amount of contamination probable on the walls, and the type of direct radiation to which they are exposed, leads to the following conclusions: (1) The effect of soft secondary radiations

or of some equivalent is definitely noticeable. (2) Immediately after the chambers are filled with fresh filtered nitrogen, radioactive contamination of the nitrogen, or something producing a like effect, is prominent for several days. At such times there is little or no evidence of contamination on the walls, presumably because any which existed previously has been removed or greatly reduced in the process of refilling. (3) Following refilling, the "volume-contamination" decreases as the radioactive material in the nitrogen diffuses and is absorbed in a thin film on the walls of the chambers. (4) After a period of from 10 to 20 days a condition of equilibrium is reached in which the "volume-contamination" is practically negligible. (5) The "volume-contamination" and the "wall-contamination" are apparently of very nearly the same density in all three chambers. Hence the fundamental idea underlying Hess's method can be expected to result in satisfactory data once the nitrogen has aged in the chambers.

A further theoretical study of the effects of secondary radiation in ionization-chambers was made (Gish), based on a discrepancy by a factor of 3 in the "Eve's value" for a Kolhörster penetrating-radiation meter, as reported by Kolhörster in 1928 and redetermined by Sherman in 1942. Assuming that the capacitance of the meter was determined originally by comparing the rate of discharge of the meter with that of a standard instrument without allowance for difference in the secondary radiation in the two, the discrepancy can be completely explained if the secondary radiation in the meter under test was much greater than that in the standard and afterward decreased with time in much the same way as the "volume-contamination" does in the Gish-Hess chambers. The validity of this explanation

is supported by the fact that the inner surfaces of the meter were electroplated with zinc and that the photoelectric effect of a fresh surface of zinc is much greater than that of a surface aged in air.

*Adaptation of electronic circuits to atmospheric-electric instruments.* An important instrumental program begun during the year was the further adaptation of electronic circuits to atmospheric-electric instruments in place of electrometers. The advantages of electronic equipment lie in greater flexibility and power of resolution, ruggedness, and convenience in recording. A satisfactory amplifier of high gain, stability, and ruggedness was completed (Sherman) and used successfully in air-conductivity measurements over a wide range of conductivity-values and difficult operating conditions. Experimental work on amplifiers for the determination of other atmospheric-electric quantities such as field-strength was also begun and shows promise, particularly in the investigation of the intense and rapidly varying fields associated with thunderstorms.

*Phenomena of thunderstorms.* Toward the end of the report-year various conferences relating to ways and means of investigating phenomena of thunderstorms were held with representatives of the United States Weather Bureau by Gish, Wait, Torreson, Rooney, and Sherman. These point toward an extensive future program in which staff members of the Department should find opportunity for extending contributions in the field of atmospheric electricity.

As a result, tentative plans were made (Gish) for the investigation of electrostatic phenomena at the Mexican volcano Parícutin. In cooperation with the United States Parícutin Committee and the United States Weather Bureau, Gish made a field-trip to the site in June 1945 to undertake a preliminary survey, including simple

measurements of electric field-strength, with a view to establishing a program for more comprehensive measurements later in the year. The work at Paricutin may be expected to be valuable in developing instruments and technique for investigation of thunderstorms.

*Rate of ionization inside a room.* The apparent response of the ionization of the air to the presence of people has previously been reported (see Year Book No. 38). Additional information (Wait) was obtained during the year. The ionization by two chambers having different wall-thicknesses was compared; one chamber with relatively thick walls excluded the ionization due to alpha particles, while the other had no covering and consequently included the alpha-ray ionization. Only the alpha-ray ionization is affected when people first come into the room. It is only after a lag of several hours that the beta- and gamma-ray ionizations show response. The results are consistent with the idea that the presence of people acts, in some manner not yet understood, to reduce the amount of radon and thoron present in the air. The effect is too large to be accounted for on the basis of the retention of radon and thoron in the lungs of the people occupying the room.

*Comparison of the rate of ionization due to gamma rays with that due to alpha rays.* The use of the two chambers also provided a comparison (Wait) of the rate of ionization by gamma and alpha rays inside a closed room. For equilibrium-conditions the alpha-ray ionization was approximately double that due to gamma rays for the particular conditions of the experiment. This ratio is about 50 per cent greater than that estimated by Eve for out-of-doors conditions.

*Annual variation in the rate of ionization of air in a room.* A large annual variation in the rate of ionization in one of

the rooms of the Department's laboratory is apparent from the records of this element during the year (Wait). A maximum value occurs in summer and a minimum in winter. The average value during the summer is about double the average value during the winter. This variation is probably due to the combination of two factors. One factor is the increased rate of exhalation of soil-gases during the summer over that during the winter season. The other factor is the increased number of condensation-nuclei in the air during the winter months over that during the summer months. It has been found from test that the ionization responds to the presence of smoke and other pollution-products in the air. The rate of ionization decreases as the amount of pollution in the air increases.

*Relation between small-ion and large-ion content of the air and the rate of ionization.* From simultaneous measurements (Wait) on the small-ion and large-ion content of the air and the rate of ionization of the air inside a room, a relation among the various elements has been obtained. The small-ion content of the air is found to vary directly as the ionization, that is, a plot of ion-content and ionization gives a straight-line relation. If the plot is extrapolated back to zero ion-content, the line passes also through the zero-value of ionization, thus indicating that the residual ionization of the chamber is small. A plot of the reciprocal of the small-ion content and the large-ion content is likewise a straight line. When extrapolated back to zero-value of the reciprocal of small-ion content, the large-ion content is not zero, but is equal to 1250 ions per cc. The ratio of ionization to the product of small- and large-ion contents is not constant, but is highest when the ionization is highest and lowest when the ionization is lowest. This ratio, theoretically, is a

measure of the average rate at which the small ion combines with a large ion.

*Alpha-ray stopping power of cellophane.* The stopping power of ordinary commercial cellophane for alpha particles was found (Wait) to be about 70 per cent as great as that of aluminum, assuming equal thickness. According to calculation the stopping power is only about one-seventh as great. There appears, therefore, considerable disparity between the calculated and the observed stopping power of cellophane.

*Errors in measuring the ion-content and the conductivity of the air.* From an analysis of the data on "mobility of the small ions" in the regular observational program aboard the *Carnegie*, information was obtained concerning the errors of observation in connection with the measurement of the ion-content and the conductivity of the air during the various cruises. It appears that, on the average, there was a systematic error, both elements being measured too low. The probable error of a single observation was around 12 to 13 per cent on all cruises, and that of the mean generally amounted to 1 per cent or less.

#### GEOELECTRICITY

Reduction of the earth-current records from Watheroo and Huancayo was kept current (Rooney) and a final summary of the records from Tucson, covering a complete sunspot-cycle, was published (Terr. Mag., vol. 49, pp. 147-157, 1944).

*Seasonal changes in diurnal variation at Tucson.* Rooney's study of the seasonal changes in diurnal variation at Tucson was completed and prepared for publication. The seasonal changes both in earth-currents and in the magnetic field at Tucson are of unusual interest because of the location of the Observatory in the transition-belt, where the type as well as the

magnitude of the variations changes markedly during the year. For the most part, the changes observed are consistent with the effects attributable to the recognized movements of the current-systems in the ionosphere northward and southward with the Sun. Two anomalous features, not so simply explained, are found in the earth-current records in addition to the regular seasonal change. The first starts just about at the winter solstice, becomes most pronounced early in January, and disappears by the end of that month. It consists of a marked increase in activity, appearing as a large increase in the amplitude of both components without any change in the phase-relation between them. During the 12 years of recording at Tucson the amplitude of variation in January was nearly twice as great as the average amplitude in December and February, and only 3 times out of 12 was it less than 50 per cent greater. Comparing earth-current and magnetic records for the 5-year period 1932-1936, a very closely parallel anomaly is found in the latter. In January the total magnetic field,  $F$ , also increases to a value well above its mean winter level, with the variations of the northward ( $X$ ), eastward ( $Y$ ), and vertical ( $Z$ ) components of the magnetic field, like the two earth-current components, all showing the same proportional increase and no change in the phase-relations between them. Moreover, the parallelism is specific and not merely statistical. During the winters of 1933-1934 and 1935-1936 the winter anomaly was unusually pronounced in the flow of earth-currents and equally strongly marked in the magnetic variations. The intervening winter, 1934-1935, was one of two in which the anomalous increase in activity was small in earth-current flow, and the magnetic data were also conspicuously less affected. This close parallelism effectively rules out structural features of the region

as the cause of the anomaly and points to a space-variation in the conductivity of the ionosphere as the most probable explanation. This space-variation must, moreover, be local rather than zonal in character; otherwise all stations at the same approximate latitude would show similar anomalies. The records from Cheltenham do show a slight trace of a similar increase in activity in January, but those from other stations do not.

The second departure from regularity in the variations at Tucson occurs in March. It is less pronounced than the winter anomaly and also less consistent in its recurrence. At this time of the year the northward component of earth-current flow is little modified and follows its normal trend toward increasing amplitude with increasing altitude of the Sun. The eastward component, on the other hand, becomes very small and erratic. Here again the parallelism with the magnetic variations is striking. As should be expected, the curve of variation in  $Y$ , like that in the northward earth-current component, is nearly normal, whereas that

for  $X$ , like the eastward earth-current vector, is reduced almost to the point of disappearance. A simple explanation of the anomaly during March can be given by assuming that during March the center of the northern current-circulation in the ionosphere shifts to the north of its general springtime position and follows a desultory course which provides an average passage just over, or slightly south of, Tucson. This explanation ignores the cause of such erratic behavior of the ionospheric currents and the question why they behave that way only in March. There is, however, other evidence that erratic shifts in the latitudes of these current-centers do take place at certain places, such, for instance, as those adduced by Hasegawa from his studies of the day-to-day changes in diurnal variation at stations in and near Japan. An examination of the magnetic records from a number of other stations situated at latitudes not greatly different from that of Tucson showed no traces of this anomaly. Hence it is probably quite local.

## THE IONOSPHERE AND ITS RELATIONS TO GEOMAGNETISM

### OBSERVATIONS

Existing stations in the coordinated program of the Ionospheric Section for ionospheric research were continued and one new station was installed in the Pacific area. In addition to the established installations of the Department at Huancayo (Peru), Watheroo (Western Australia), and College (Alaska), five other overseas ionospheric observatories are being operated. All these stations continued to provide ionospheric data, using automatic recorders giving essentially complete records for 24 hours each day with the exception of brief interruptions for adjustment or maintenance of equipment.

The automatic ionospheric recorders of DTM design and construction have been in continuous operation at Huancayo Magnetic Observatory since 1937 and at Watheroo Magnetic Observatory since 1938. Performance of these instruments continues to be satisfactory although they have more than completed their normal expectancy of useful service. At the Huancayo Magnetic Observatory the new ionospheric laboratory was constructed, with additional facilities for field-intensity recorders.

Organization of the solar observational program for the purpose of short-term forecasting of ionospheric and magnetic

disturbances continues essentially as in the previous years. Daily reports of solar observations are received from United States Naval Observatory, Mount Wilson Observatory, Harvard College Observatory at Climax (Colorado), and the McMath-Hulbert Observatory. In addition to the above, frequent reports from other groups continue to be helpful in studying the progress of solar activity.

#### RESEARCH AND DEVELOPMENT

An active program of research and development was maintained at the Kensington Ionospheric Laboratory and at the several field-stations. Activities of the Kensington Laboratory were directed toward development and construction of improved and simplified manually operated ionospheric equipment with a considerably extended frequency-range. Development at the field-stations included improvements to existing equipment with appropriate modifications to assure uninterrupted registration of ionospheric characteristics.

Construction of four additional field-intensity recorders was completed; and these were installed at the Huancayo Magnetic Observatory. Subsequent to the installation, certain specific tests were conducted to determine the effectiveness of fringe-type  $E$ -layer reflections and  $F_2$  scatter signals in supporting radio-wave propagation.

#### COOPERATIVE ACTIVITIES

Fleming and Wells maintained active participation in the Wave Propagation Committee of the Joint Communications Board, and continued to cooperate in a consulting capacity with authorized Army and Navy representatives in matters concerning the ionosphere, geomagnetic activity, and radio-wave propagation. The Committee, composed of Army and Navy

members and of representatives of the Interservice Radio Propagation Laboratory (IRPL) and the Carnegie Institution of Washington, controls activities of the IRPL and the CIW as regards radio-wave propagation matters.

During the year two complete teams of Signal Corps personnel were trained for overseas assignment and training of a third team was started. Facilities of the Kensington Ionospheric Laboratory and the Department were also devoted to a program of equipment-development sponsored by the Radio Propagation Section of the United States Army Signal Corps. Sergeant Peter G. Sulzer was principally responsible for the development of a manual ionospheric recorder using a 12-inch cathode-ray tube. In addition, a promising version of an automatic recorder was constructed; satisfactory preliminary tests on this unit indicate that it may provide the basic design for equipment which will ultimately replace existing automatic ionospheric recorders.

Particularly close liaison was maintained with the Australian and Canadian Radio Wave Propagation Committees. A complete manually operated recorder was constructed and loaned to the Canadian group for expansion of its observational program. Canadian and Chinese representatives were trained to operate ionospheric equipment and to interpret results.

#### REPORTS AND PAPERS

A paper on "Sporadic- $E$  ionization at Watheroo Magnetic Observatory" was presented by Wells at the May meeting of the American Geophysical Union. The paper was based on analyses of ionospheric records for June 1938 to December 1941. Seasonal features of sporadic- $E$  already established for the Northern Hemisphere were confirmed for the Southern Hemis-

sphere with maximum occurrence in local summer months. Annual trends show increasing values during 1938 to 1941, suggestive of an inverse relation to solar activity. Tests for recurrence-tendencies of sporadic-*E* with the 27-day solar rotation period did not show any positive correlation.

#### Postwar Plans

Postwar activities of the Ionospheric Section must be preceded by a period of at least several months to readjust personnel from highly specialized war activities to the broader fields of peacetime research. During this period attention must be given to assimilation of progress made by other groups or agencies in ionospheric and related fields of research.

The general plan for ionospheric research should include both observational activities at the Huancayo and Watheroo magnetic observatories and definite investigational projects. Certain equipment, for example the automatic multifrequency apparatus—designed and constructed in 1935 and 1936—needs to be replaced in view of new and improved techniques developed since 1940. Because of the impending probable loss of our Kensington Ionospheric Station on account of building operations close by and the resulting radio disturbances, a new field-station and site of sufficient area to ensure protection against encroachment of other interests will be necessary.

The present observational program at both Huancayo and Watheroo should be maintained through 1950 so that registration of ionospheric characteristics at each observatory may be complete for a sunspot-cycle. Subsequent to 1950, control-observations of a simplified nature will be sufficient to fulfill civilian and military requirements for ionospheric data from these locations.

Important items of postwar research are

(1) extended analyses of accumulated data and (2) new projects directed toward specific problems for which positive solutions may be expected in a reasonable length of time. There are many short-term projects of a fundamental character which merit immediate prosecution and do not involve additional long-term observational programs. Six specific projects of this kind were listed in the Department's report in Year Book No. 43 (p. 34).

*Personnel.* Wells spent several months in Australia on a war mission. During this assignment he visited the Watheroo Magnetic Observatory and conferred with Observer-in-Charge Parkinson and members of the staff. Seaton, of the College Observatory, spent several weeks during February 1945 at Washington in special conferences. He has also been active in connection with the proposed Geophysical Institute for the University of Alaska at College. Ledit and Jones, of the Huancayo Magnetic Observatory, spent several months at the Department on a rotation plan, for conferences and instructions regarding instrumental improvements and new techniques for interpretation of ionospheric records.

Activities of temporary staff members were as follows: Hluchan returned from his Arctic assignment in October 1944, and subsequently installed the new field-intensity recorders at the Huancayo Magnetic Observatory. Max returned from his overseas assignment and has accepted other employment. Peavey returned from his Arctic assignment and was subsequently reassigned to a Pacific station. Goldman returned from his overseas station to accept assignment as observer-in-charge of an Arctic station. Ventre made a brief trip to the Department for certain urgent repairs to equipment. Huebsch, after contributing materially to development work at Kensington, was assigned to a new

Pacific station. The services of Watts in the Pacific area have been particularly helpful in the establishing of new stations and in the training of personnel. Easley accepted a second year's assignment to an isolated Arctic station, thereby providing an extremely valuable continuity of personnel which greatly facilitated the performance of this station. Settle was returned from his Arctic station by special plane as a result of inability to adjust himself to conditions of Arctic life. Murray, W. G. Johnson, and Sullivan continued in their overseas assignments and maintained continuity of observations in spite of occasional handicaps due to both instrumental failure and effects of environment. Halpin and Stansbury returned from College after completion of their tour of duty and will establish another

new station in the Pacific area. Schmieder assisted in developmental work at the Kensington Laboratory prior to his assignment to the College station. Other members of the College staff, including Wolff, Malich, Kowalak, Rolfe, Wilder, Bliss, and E. F. George, contributed materially to the successful program throughout the year. Gammon was trained in the use of ionospheric equipment and interpretation of records; he is soon to take an overseas assignment. D. E. George was engaged at the Kensington Ionospheric Laboratory. Shapley worked primarily on the short-term forecasting program and assisted in the training of personnel. Miss Hodder aided Shapley in the successful forecasting program. Miss Follin engaged in special investigational work and Miss Puffer in secretarial work of the Section.

#### MAGNETISM AND ATOMIC PHYSICS

Cowie had charge of the 60-inch cyclotron with the assistance of Ksanda, P. Johnson, Buynitzky, and Mendousse. (Dr. Mendousse, captain in the French Army, continued to be made available through the courtesy of the French Military Mission in Washington.) These five men kept the cyclotron in operation throughout the report-year.

Tuve, Hafstad, Roberts, Green, and Heydenburg of the nuclear-physics group were engaged full time during the report-year on war-research activities or in the Services.

As in the past year, lack of personnel prevented further improvements to, and operation of, the large static generator in the Atomic-Physics Observatory and the small one in the Experiment Building.

#### CYCLOTRON

The fact that the cyclotron was in almost continuous daily operation without any major breakdowns and with few

minor changes was fortunate because it made available long and dependable bombardments for special purposes.

Most of the operation was devoted to researches in which this Department collaborated with the Navy, Army, and Public Health Service. The staff, laboratories, and equipment of the Department, coupled with the scientific and medical personnel of the above groups and their facilities, made possible the organization of well equipped research teams. This is very important because no one man can meet the requirements for a clinician, chemist, physicist, pathologist, and biologist, or do justice to an investigation requiring the knowledge of such specialists. The assignment of specialists in each field by the collaborating agencies permitted rapid and efficient organization of a team in which each individual became responsible for a fraction of the work done. Some of the more interesting results obtained can now be reviewed.

The Division of Zoology of the United States Public Health Service attempted to correlate, by means of radioactive-tracer techniques, the localization of heavy metals in the body and their chemotherapeutic activity. Filariasis, schistosomiasis, and other diseases in which the heavy metals serve as chemotherapeutic agents were studied. Drs. Frederick J. Brady (Acting Chief of the Zoology Laboratory), Alfred H. Lawton, and A. T. Ness took part in this research, some of the results of which are as follows:

(1) The blood and tissue distribution of antimony was determined following single-dose administration of radioactive trivalent compounds of antimony to dogs naturally infected with *Dirofilaria immitis*.

(2) The specific uptake of the antimony by the adult worm and the subsequent elimination of the microfilarids from the blood-stream were established.

(3) An unexpected high concentration in the thyroid of the dogs followed single-dose treatment with the compounds of antimony. This organ, 24 or 36 hours after injection, appears to have a concentration greater than any tissue except the liver. In two cases, 7 days after a single treatment with tartar emetic, the thyroid was the highest of all tissues in the dogs.

(4) After 12 injections of antimony over 14 days, the thyroid was highest in antimony concentration of all the 36 tissues studied. Attempts are being made to see if this thyroid concentration is related to toxicity or to chemotherapeutic effect.

(5) Cotton rats naturally infected with *Litomosoides carinii* and treated with single doses of radioactive arsenic (sodium arsenite) showed a specific arsenic uptake by the adult filarids similar to the antimony uptake by the *Dirofilaria immitis*. The thyroid in these arsenic-treated animals showed no large arsenic concentration.

(6) White rats, when treated with either arsenic or antimony, showed quite anomalous tissue distribution. In fact, these laboratory animals retained in the blood for several days most of the arsenic and antimony injected intravenously as sodium arsenite or as tartar emetic, in contrast with the rapid elimination by chicks, cotton rats, dogs, rabbits, guinea pigs, and hamsters. This is rather significant, since the white rat has been the standard laboratory animal for arsenic chemotherapy studies for many years.

Two papers on the results were published (see bibliography at end of report) and another is in press under the title "The distribution of radioactive arsenic following intraperitoneal injection of sodium arsenite into cotton rats infected with *Litomosoides carinii*," by Alfred H. Lawton, A. T. Ness, Frederick J. Brady, and Dean B. Cowie.

Drs. J. M. Steele, R. E. Smith, and R. E. Eakin, of the Naval Medical Research Institute, initiated a vigorous program of antimony research. The medical and military importance of antimony therapy and the problems which are rising from its use justify the priority given this element. The pharmacological investigations of antimony reported above deal entirely with trivalent and pentavalent compounds. This Navy group, therefore, is investigating antimony in its two other valency states, -3 and 0. Stibine was found to be therapeutically effective against malarial parasites in chick erythrocytes, and the antimony distribution following stibine therapy was determined using radioactive antimony. The significant finding of the study was the unusually high antimony content of the red blood cells immediately following stibine therapy. Studies were made on the chemical fate of stibine in the body. *In vitro* experiments with blood and blood fractions in-

dicate that: (a) stibine, during the gaseous exchange in the lung, is taken up almost entirely by the red cells; (b) stibine is almost instantaneously decomposed, antimony being trapped within the red cells in the colloidal form as metallic antimony; (c) this extremely rapid decomposition of stibine in the red blood cells is catalyzed by hemoglobin; and (d) this catalytic action of hemoglobin is apparently unique, inasmuch as no other biological agent has been found which will cause this rapid reaction. The reaction is independent of the oxygen tension or the presence of oxidizing agents. The conclusion from these findings is that stibine itself is not the therapeutically active agent, but that it serves as a method of producing a high concentration of metallic antimony within the red cells. It is believed possible to establish beyond all doubt the identity of hemoglobin as the stibine-decomposition catalyst, and determine the quantitative relations of this phenomenon.

A method was developed for making a stable colloidal preparation of metallic antimony which is entirely free from other forms of antimony. A nonradioactive preparation was made for therapeutic testing against the extra-erythrocytic stage of a malaria parasite in the chicks. Radioactive samples are being prepared which will be used for *in vitro* and *in vivo* distribution and metabolism studies.

A series of hamsters infected with *Schistosoma mansoni* and their normal controls were injected with radioactive tartar emetic and the antimony distribution was measured as a function of time in the blood, tissues, and parasites. Significantly it was found that there was a marked accumulation in the liver and thyroid. The adult flukes also showed this specific uptake. The orders of rank of tissue and parasite concentration at 48 hours confirmed in exact detail the findings of the United

States Public Health Service on the 36-hour dogs infected with *Dirofilaria immitis*. No outstanding differences were found between the controls and the infected hamsters. The marked and progressive accumulation by the liver and the thyroid perhaps indicates that toxicity of antimony may be related to these findings.

Jane Strane, Ensign, Robert Englert, HA 1/c, Louis P. Cecchini, PhM 3/c, and Morton Harfenist, PhM 3/c, assigned from the Naval Medical Research Institute to the Department, have greatly assisted in the progress of the antimony research. C. J. Spear, PhM 1/c, R. L. Evans, PhM 2/c, L. H. Gordon, PhM 2/c, and F. N. Gillespie, PhM 2/c, assisted both at the Department and at the Naval Medical Research Institute.

Ksanda assisted in many of the radioactive measurements of biological samples in the above cooperative research projects. Buynitsky and Ksanda provided any improvements in the cyclotron that were found necessary during the year and maintained a supply of ion-source filaments and additional target and ion-source assemblies. P. A. Johnson, with Mendousse and Cecchini, developed new probe-targets which permit large beams with maximum cooling. This work is important for the operation of cyclotrons, since large yields from probe-target bombardments are thereby made possible. Antimony, phosphorus, arsenic, and tellurium are some of the newer targets worked on. Johnson was responsible for the numerous target-holders and the daily target-supply. Buynitsky was in sole charge of the operation of the cyclotron. Since the instrument has been running so efficiently with little or no trouble, almost automatic operation has resulted.

A new ion-source was developed permitting 80 to 90 hours of operation. Large, steady beams are possible with this source,

which has a direct-current filament supply (motor-generator) and a constant-current network for the arc-current. A paper by Cowie and Ksanda describing this ion-source is in press.

Among other organizations which utilized the facilities of the cyclotron were the National Defense Research Committee, the Army, the National Bureau of Standards, and the Department of Agriculture.

The administrative officers of the Naval Medical Research Center and of the Public Health Service, by their encouragement and assistance, have contributed much to the success of these collaborative researches.

#### MISCELLANEOUS

Besides the reports which are noted above, two Bureau of Medicine of the Navy reports were prepared as follows: "Quantitative analysis of antimony evaluation of Maren's modification of Webster's rhodamine-B method by means of radioantimony," by Lois F. Hallman, Lieutenant (jg); Cyrus J. Spear, PhM 1/c; and Dean

B. Cowie. "The distribution of radioactive antimony in hamsters infected with *Schistosoma mansoni* with particular reference to accumulation by the thyroid," by R. E. Smith, Dean B. Cowie, Robert E. Eakin, and C. H. Hill.

Lectures relating to the collaborative use of the cyclotron in the several investigations were presented as follows: On localization of trivalent radioactive antimony following intravenous administration (see bibliography at end of report), at Fortieth Annual Meeting of American Society of Tropical Medicine, St. Louis, Missouri, November 1944. On the cyclotron and artificial radioactivity, by Dean B. Cowie, before Biochemistry Seminar, National Institute of Health, Bethesda, Maryland, March 1945. On use of radioactive substances in biology with special reference to uptake of antimony by *Dirofilaria immitis*, by F. J. Brady, D. B. Cowie, and A. H. Lawton, at Helminthological Society, Washington, D. C., April 1945.

As in 1944, the Annual Conference on Theoretical Physics was not held because of limitations of time and travel.

### FIELD-WORK AND REDUCTIONS

#### LAND MAGNETIC SURVEY

The manuscript of a new volume (VIII) of the Researches of the Department of Terrestrial Magnetism was revised to include results of recent cooperative surveys in 1944 and the finally compiled magnetic data obtained aboard the *Carnegie* during 1928-1929 on the last cruise of that vessel. It is hoped this volume may be published in 1946.

The compilations of world-wide secular changes in declination (*D*), horizontal intensity (*H*), inclination (*I*), vertical intensity (*Z*), total intensity (*F*), north intensity (*X*), and east intensity (*Y*) described in last year's report were com-

pleted. The results in intensity in particular have been considerably improved by removing the effects of various geomagnetic fluctuations from the data of observatories and at stations on land and sea used in estimating secular change. The results were plotted on large-scale Mercator and polar projections for the four epochs 1912.5, 1922.5, 1932.5, and 1942.5.

Isoporic charts for declination and horizontal intensity for the four epochs were completed, except for minor modifications near the principal magnetic dip-poles based on theoretical study now under way. These new charts show substantial im-

provements over previous estimates of secular change made in many regions. There remains, however, some uncertainty regarding the magnitude of secular change in certain polar and oceanic areas—a defect that can be effectively remedied only by future measurements in these areas. The sparsely stationed areas have been bridged, with a degree of success difficult to assess, by using the line-integral and curl-tests of potential theory. In this way the *D*- and *H*-isoporics have been drawn so that they are mutually consistent for the first time to a good degree of approximation, mainly by suitable adjustments of contours over oceanic and polar areas. Care was also taken to draw the contours in conformity with singularities present in field—a feature neglected in previous charts, as pointed out recently by Chapman. Good use has also been made of the opportunity to compare the new charts with one another at adjacent ten-year epochs in arriving at the final estimated contour-lines for each epoch in secular change.

Noteworthy features are the existence of large positive foci in *D*- and *H*-isoporics for the South Polar region, and the great and remarkable changes both in magnitude and in pattern which have appeared in many regions during the relatively short time-interval of only 40 years in the Earth's history.

Isoporic charts for the remaining components are in construction and will be adjusted, in so far as is deemed advisable, to mutual consistency with the *D*- and *H*-isoporic charts.

Isomagnetic charts of *D*, *H*, and *Z* for the Western Pacific area were completed, including magnetic anomalies observed or estimated in cooperation with the United States Geological Survey. The isomagnetic world-chart for declination, in 17 sections, is nearing completion.

Loan was maintained, as in the past,

of field-instruments and equipment to seven observatories in surveys in South America, South Australia, Northern Australia, New Zealand, British East Africa, Belgian Congo, South Africa, and the United States, as well as to other organizations. International magnetic standards and corrections thereto were maintained in cooperation with the United States Coast and Geodetic Survey at the Cheltenham Magnetic Observatory.

Tables of departures in geomagnetic field used in estimating secular change were extended to December 31, 1944.

#### FIELD-OPERATIONS AND COOPERATIVE SURVEYS

*Africa.* Dr. A. Walter, Director of the British East African Meteorological Service, continued observations in Tanganyika Territory using CIW magnetometer and inductor 13.

Dr. A. Ogg, of the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa, Hermanus Observatory, continued frequent and valuable observations using CIW magnetometer-inductor 17. In June 1945 CIW magnetometer-inductor 17 was transferred to G. Heinrichs for use as standard instrument at the Elisabethville Magnetic Observatory in the Belgian Congo.

*Australia.* Chief Geophysicist J. M. Rayner and L. A. Richardson continued valuable and extensive surveys in Australia as a cooperative endeavor of the Aerial, Geological, and Geophysical Survey of Northern Australia, Department of Supply and Development, Canberra, and the Department of Terrestrial Magnetism. During June to December 1944, 34 stations were occupied in South Australia, Western Australia, New South Wales, and Northern Territory. In this work assistance was rendered by Observer-in-Charge W. C. Parkinson of the Watheroo Magnetic Observatory, and W. D. Parkinson of the Observatory accompanied Mr. Richardson on a field-trip September 29 to November 17, 1944. The results of the survey, with earlier data

obtained by the Department, were used to construct a fine series of maps of declination covering Australasia.

CIW magnetometer 6 and dip-circle 226 were continued on loan to Astronomer G. F. Dodwell for use in measurements in South Australia.

*New Zealand.* Director H. F. Baird of the New Zealand Magnetic Survey, New Zealand Department of Scientific and Industrial Research, continued the active and valuable survey-program in New Zealand using CIW magnetometer-inductor 27.

*North, Central, and South America.* CIW

magnetometer 26 was used by the United States Coast and Geodetic Survey in extensive resurveys in the Western Hemisphere, financed by the United States Department of State.

CIW universal magnetometer 19 was loaned to the United States Lake Survey Commission at Detroit, Michigan, for use in determining magnetic declination.

Major S. Graceras, Chief of the Division of Geodesy, Military Geographic Institute, Uruguay, is using CIW magnetometer-inductor 28 in a survey of 60 field-stations in Uruguay.

#### OBSERVATORY-WORK

The activities of the Section of Observatory-Work continued under the direction of Johnston, assisted by Scott and Miss Balsam. By far the greater part of the time during this report-year was devoted to work relating to the war. Wait continued investigations relating to atmospheric electricity. Torreron (from January 1 to June 30, 1945), with the assistance of Mrs. R. M. Crow, was engaged in preparation of manuscript reporting the atmospheric-electric results obtained on Cruise VII of the *Carnegie*. McNish continued to be occupied with war-research work. The various members composing the staffs at the observatories are mentioned under the heading "Operations at observatories."

The magnetic, earth-current, and ionospheric programs were continued at the Watheroo, Huancayo, and College observatories. The observations were analyzed upon receipt at the Washington office. Weekly summaries of magnetic and ionospheric data, predictions of maximum usable frequencies for various distances, and current forecasts of conditions affecting radio communications were supplied various bureaus and organizations of the government.

Continuous photographic records of the three magnetic elements and the heights of the ionosphere by means of fixed and automatic multifrequency transmissions were obtained at Watheroo, Huancayo, and College. Atmospheric potential-gradient, positive and negative conductivity of the atmosphere, earth-currents, solar observations by means of a Hale spectrohelioscope, and meteorological values were recorded at Watheroo and Huancayo. The cosmic-ray meter and the three-component seismograph continued in operation at Huancayo. During the spring of 1945, signal-intensity equipment was installed at Huancayo.

The reductions of magnetic data and computations in connection with the analysis of magnetic results from Watheroo, Huancayo, and College observatories were carried forward. The values of the magnetic elements for these three observatories for 1944 were completed and made available to numerous interested organizations. The mean annual values of the magnetic elements for all days of 1943 and 1944 for Watheroo and Huancayo are shown in table 1; those for College, Alaska, are given under "Operations at observatories."

The collection of data from a network

of world magnetic observatories for use as a criterion of geomagnetic activity was continued as in previous years. Those observatories cooperating supply indices of activity (range from 0, very quiet, to 9, extremely disturbed) for each three-hour period during the Greenwich day. Reports of activity-indices were received from 29, 28, 27, and 27 magnetic observatories for the years 1941 to 1944, respectively.

tabulated all the *K*-indices received from world observatories for the three years 1941-1943. The mean indices were computed and tabulated. Final summaries were prepared for each of the years. A short paper entitled "Mean *K*-indices from twenty-seven magnetic observatories and preliminary international character-figures for 1943" was prepared for the *Journal of Terrestrial Magnetism and Atmospheric*

TABLE I

ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED ON MAGNETOGRAMS FOR ALL DAYS, 1943 AND 1944

YEAR	DECLI- NATION, <i>D</i>	INCLI- NATION, <i>I</i>	INTENSITY-COMPONENTS					LOCAL MAG- NETIC CON- STANT, <i>G</i>	
			Hori- zontal, <i>H</i> ( $\gamma$ )	Total, <i>F</i> ( $\gamma$ )	North- south, <i>X</i> ( $\gamma$ )	East- west, <i>Y</i> ( $\gamma$ )	Vertical, <i>Z</i> ( $\gamma$ )		
WATHEROO MAGNETIC OBSERVATORY									
1943.....	3° 04.4' W	64° 25.4' S	24718	57254	24682	-1325	-51643	35745	
1944 .....	3 01.1 W	64 25.2 S	24745	57310	24711	-1303	-51693	35782	
HUANCAYO MAGNETIC OBSERVATORY									
1943.....	6 40.0 E	2 11.5 N	29400	29422	29201	3413	1125	29405	
1944.....	6 34.8 E	2 10.3 N	29367	29388	29174	3365	1114	29372	

Reports of *K*-indices from seven American-operated observatories, as also those from College (Alaska), Toolangi (Victoria, Australia), and Godhavn and Ivigtut (Greenland), were compiled and circulated weekly. Fifty-two issues of "Report of geomagnetic activity" (DTMCIW nos. 389-440) were prepared and furnished to organizations and individuals requiring this information.

Summary of magnetic activity for 1944 was completed, including graphing of American magnetic character-figures and mean *K*-indices.

Johnston, with Miss Balsam's assistance,

*Electricity*. The regular quarterly reports of American character-figures and *K*-indices were prepared for publication. The five international quiet and disturbed days were selected for the months of 1944.

The compilation of annual values at geomagnetic observatories of the world for publication in the form of a thesaurus was continued by Fleming and Scott.

Cooperative work in magnetism and atmospheric electricity was continued with various magnetic observatories. International magnetic standards were maintained at the Cheltenham Magnetic Observatory. The Department cooperated with the

Danish government in operating the Godhavn and Ivigtut magnetic observatories in Greenland.

Scott made a complete field-station at the Radio Station of the National Bureau of Standards, near Sterling, Virginia, during November 1944. He also assisted Vestine and Sherman in the adjustment and operation of the CIW visual-recording *H*-variometer installed there in the field-intensity building. CIW universal magnetometer 19 was standardized at the Cheltenham Magnetic Observatory.

In May 1945, Johnston and Scott, with Dalke of the temporary staff, made a preliminary magnetic survey of conditions in and near the "Quiet house" during construction of the Magnetic Laboratories of the Naval Ordnance Laboratory at White Oak, Maryland.

#### OPERATIONS AT OBSERVATORIES

*Watheroo Magnetic Observatory, Watheroo, Western Australia.* The Watheroo Magnetic Observatory is situated in latitude  $30^{\circ} 19' 1$  south and longitude  $115^{\circ} 52' 6$  east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was in continuous operation. Only 6 hours of trace was lost during the calendar year 1944—this due to a failure of the recording lamp. The scale-value of the horizontal-intensity variometer was controlled, as in previous years, by monthly determinations using the magnetic method. Scale-value determinations of the vertical-intensity variometer were made daily by the electrical method.

The la Cour rapid-running magnetograph was also operated throughout the year, monthly determinations of scale-values of both horizontal and vertical intensities being made by the electrical method. The monthly scale-values for the year 1944 for both Eschenhagen and la Cour magnetographs are shown in table 2. The determinations of scale-values for declination were: Eschenhagen variom-

eter on October 31, 1944, 1.032 per mm; la Cour variometer on November 15, 1944, 1.044 per mm.

Weekly determinations of the base-line values of the Eschenhagen variometers were made in the absolute observatory using CIW magnetometer 7 and CIW earth-inductor 2. A redetermination of the moment of inertia of magnet  $\gamma L$  and suspension was made

TABLE 2

SCALE-VALUES OF MAGNETOGRAPHS, WATHEROO MAGNETIC OBSERVATORY, 1944

MONTH	SCALE-VALUES IN $\gamma/\text{MM}$			
	ESCHENHAGEN		LA COUR	
	<i>H</i> (reduced to base- line)	<i>Z</i> (means of daily values)	<i>H</i>	<i>Z</i>
January...	2.43	3.15	4.69	3.27
February...	2.41	3.06	4.52	3.25
March.....	2.43	3.09	4.48	3.52
April.....	2.41	2.96	4.64	3.39
May.....	2.43	2.94	4.49	3.68
June.....	2.42	3.06	4.55	3.70
July.....	2.43	3.13	4.75	3.85
August....	2.43	3.16	4.89	3.78
September.	2.43	3.04	4.78	3.76
October....	2.42	3.18*	4.59	3.52
November.	2.43	3.48	4.59	3.41
December..	2.43	3.53	4.60	3.52

\* Mean value of several base-line shifts.

during July 1944. During September 1944 complete intercomparisons were made between the observatory standard absolute instruments and CIW magnetometer-inductor 18, which has been extensively used by L. A. Richardson, of the Mineral Resources Survey of Australia. Mr. Richardson also made a magnetic survey of the vicinity of the Observatory, and the results disclosed a remarkably uniform distribution.

The preliminary mean values of the magnetic elements for all days of 1944, as deduced from the Eschenhagen magnetograms, refer-

ring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, indicate annual changes as follows: declination,  $+3'3$ ; horizontal intensity,  $+27$  gammas; inclination,  $+0.2$  (see table 1 for annual mean values).

As a criterion of geomagnetic activity, three-hour-range *K*-indices, on a scale of 0 to

9, were assigned from the Eschenhagen magnetograms and transmitted daily to Mount Stromlo, weekly to Washington, and monthly to the Radio Research Board, Sydney. Table 3 shows the mean monthly *K*-indices for 1944 for the three-hour periods.

Six magnetic storms were recorded during 1944, and table 4 gives the essential details of these disturbances.

TABLE 3

MONTHLY MEAN FOR THREE-HOUR-RANGE *K*-INDICES, WATHEROO MAGNETIC OBSERVATORY, 1944

MONTH	GREENWICH MEAN HOURS								MEAN FOR MONTH
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24	
January....	1.8	1.8	1.9	2.1	2.9	2.7	2.4	1.9	2.2
February....	1.5	1.6	1.9	1.9	2.5	2.2	1.9	1.7	1.9
March.....	2.1	2.0	2.4	2.8	2.8	2.6	2.5	2.2	2.4
April.....	1.6	1.9	2.2	2.4	2.4	2.3	2.2	1.6	2.1
May.....	1.4	1.6	1.6	2.0	1.9	1.8	1.9	1.5	1.7
June.....	1.3	1.7	1.9	1.8	1.9	2.1	1.7	1.8	1.8
July.....	1.3	1.6	1.7	1.8	1.6	1.7	1.7	1.4	1.6
August....	1.7	1.9	1.9	2.1	2.1	2.0	1.9	1.6	1.9
September..	1.9	2.0	2.0	2.1	2.1	1.9	1.9	1.8	2.0
October....	1.8	1.6	1.6	2.0	1.4	2.3	2.1	1.5	1.8
November..	1.4	1.3	1.5	1.7	1.8	1.6	1.4	1.4	1.5
December ..	2.4	2.5	2.4	2.4	2.3	2.7	2.3	2.3	2.4
Year.....	1.7	1.8	1.9	2.1	2.1	2.2	2.0	1.7	1.9

TABLE 4

DETAILS OF MAGNETIC DISTURBANCES RECORDED  
AT WATHEROO MAGNETIC OBSERVATORY  
DURING 1944

DATE	RANGES		
	<i>H</i> ( $\gamma$ )	<i>D</i> ( $'$ )	<i>Z</i> ( $\gamma$ )
February 7-8.....	113	20	147
March 26-27.....	154	20	114
April 2.....	320	27	>184
May 1.....	115	15	92
September 30.....	77	11	88
December 15-18*....	263	32	>197

\* Aurora observed.

The continuous registration of earth-potentials using a system of electrodes, which has been described in previous reports, was carried on throughout the year. Loss of trace from instrumental causes was small although magnetic storms and damage to aerial lines necessitated the rejection of some days in the tabulations. Scalings and reductions are current and the diurnal-variation curves of the four lines give consistent results. Many poles supporting the lines were replaced by substantial white-gum poles and the wires were tightened. The batteries used for the balancing current in the recorder were installed in the lobby of the Atmospheric-Electric Observatory in March 1944 and are charged from the direct-current instrument line. The

conducting lines were regularly patrolled and defects promptly remedied.

Air-potentials were continuously recorded throughout the year and the results tabulated and reduced. Standardization observations, for the reduction of the values from the recorder to volts per meter, were made on January 24, August 7, and December 11, 1944. Some trouble during May 1944 in the insulation of the collector was reme-

tion, the only breaks in registration being occasioned by maintenance, calibration-checks, minor repairs, and adjustments to the apparatus. Various replacements of wearing parts were made as required. An alarm circuit, connected to the interphone system, was installed in September 1944 and gives warning of any instrumental failure which causes a shutdown of the equipment. Minor repairs to the antenna systems were made whenever

TABLE 5

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
WATHEROO MAGNETIC OBSERVATORY, 1944

MONTH	POTENTIAL-GRADIENT			AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
	No. selected days	Reduction-factor	Value* (V/m)	No. selected days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January.....	8	1.24	114	10	1.23	1.25	2.48	0.98
February.....	4	....	120	8	1.32	1.22	2.54	1.08
March.....	7	....	94	13	1.70	1.58	3.28	1.08
April.....	21	....	73	24	1.87	1.78	3.65	1.05
May.....	16	....	77	24	2.12	1.96	4.08	1.08
June.....	24	....	62	26	2.60	2.38	4.98	1.09
July.....	15	....	82	24	2.20	1.77	3.97	1.24
August.....	25	1.12	85	29	2.08	1.64	3.72	1.27
September.....	25	....	89	20	1.91	1.43	3.34	1.34
October.....	25	....	92	27	1.79	1.48	3.27	1.21
November.....	16	....	100	25	1.62	1.35	2.97	1.20
December.....	18	....	100	26	1.46	1.35	2.81	1.08
Totals and means.....	204	1.18	91	256	1.82	1.60	3.42	1.14

\* Using reduction-factor 1.10 as previously determined, because value observed in January is poor.

died. Weekly calibrations of the recording electrometer were made. Table 5 gives the monthly mean air-potentials for 1944 in volts per meter, using a reduction-factor of 1.10.

Positive and negative air-conductivities were continuously recorded throughout the year and weekly calibrations made. Adjustment of the apparatus was made as required, and scalings and reductions are current. Table 5 gives the monthly mean values of positive and negative conductivities, their sums, and ratios.

The automatic multifrequency ionospheric recording apparatus was in continuous opera-

necessary, and all halyards were replaced by new weatherproofed rope in October 1944. Daily reports of hourly ionospheric conditions were transmitted to Mount Stromlo through the Department of Air, and copies of monthly mean hourly values were sent to the Department of Air, the Radio Research Board at Sydney, the Department of Scientific and Industrial Development of New Zealand, His Majesty's Australian Navy, and Washington. Photographic copies of ionospheric tabulations were also supplied to various organizations. Table 6 gives the mean hourly values of

ionospheric data for the calendar year 1944, and table 7 shows the monthly mean values for the same period. It will be noted from tables 6 and 7 that changes were made during the year in the elements tabulated; this was in accordance with the decisions reached at the International Radio Propagation Confer-

logical data were regularly supplied to the Commonwealth Weather Bureau in Melbourne. A daily journal of weather was kept. The reduction of the meteorological data is reasonably current. The year 1944 was very deficient in rainfall, the total being about 4 inches below the average. Table 8 shows the

TABLE 6  
PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,  
WATHEROO MAGNETIC OBSERVATORY, 1944

120° east meridian time (h)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	$f_E^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)	MUF* 3500 km (Mc/sec)	MUF† 3000 km (Mc/sec)	$f_{Es}^†$ (Mc/sec)
00.....	...	327	253	...	...	3.65	...	9.8	11.3	3.1
01.....	...	318	248	...	...	3.61	...	9.8	11.2	3.2
02.....	...	311	242	...	...	3.51	...	9.8	11.2	3.2
03.....	...	305	240	...	...	3.39	...	9.7	10.6	3.2
04.....	...	301	239	...	...	3.26	...	9.7	10.1	3.0
05.....	...	294	236	...	...	3.14	...	9.0	10.4	2.8
06.....	...	280	237	...	...	3.39	...	9.6	12.2	3.0
07.....	...	270	247	2.03	...	4.41	...	13.2	15.0	3.7
08.....	...	278	280	2.52	...	5.04	0.70	15.1	16.8	3.6
09.....	...	295	307	2.80	...	5.43	0.79	16.0	17.6	3.8
10.....	219	304	318	2.97	4.19	5.63	0.88	17.0	18.6	3.9
11.....	212	315	319	3.03	4.25	6.07	0.91	17.3	19.0	4.1
12.....	213	310	310	3.05	4.27	6.38	0.91	18.0	20.3	4.2
13.....	214	312	308	3.04	4.25	6.53	0.91	18.3	21.1	4.1
14.....	219	306	300	3.01	4.19	6.57	0.88	18.9	21.0	4.1
15.....	221	298	287	2.89	4.04	6.46	0.81	19.1	20.6	3.8
16.....	...	287	273	2.58	...	6.18	0.74	18.7	20.1	3.6
17.....	...	280	255	2.16	...	5.72	...	17.6	19.0	3.3
18.....	...	280	230	...	...	5.03	...	14.7	17.2	3.1
19.....	...	293	229	...	...	4.41	...	12.3	14.7	2.9
20.....	...	307	234	...	...	4.11	...	11.2	13.2	2.9
21.....	...	319	246	...	...	3.87	...	10.3	12.3	2.8
22.....	...	325	250	...	...	3.75	...	9.7	11.9	2.8
23.....	...	329	255	...	...	3.69	...	9.6	11.6	3.0

\* January to June only.

† July to December only.

ence held at Washington in May 1944. Scalings and reductions are maintained strictly current.

The full program of observation and automatic recording of the meteorological elements was maintained. Coded reports on weather were prepared and transmitted thrice daily to the RAAF forecasting station in Perth, and monthly summaries of meteoro-

monthly rainfall at the Observatory during 1944.

The continued manpower shortage limited the amount of repair, maintenance, and improvement work on buildings and site; however, all urgently necessary repairs and maintenance work were done.

W. C. Parkinson continued as Observer-in-Charge and W. D. Parkinson as part-time

TABLE 7

PRELIMINARY MEAN MONTHLY VALUES OF IONOSPHERIC DATA,  
WATHEROO MAGNETIC OBSERVATORY, 1944

Month	$h_{F_1}^{up}$ (km)	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{up}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	$f_E^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)	MUF 3500 km (Mc/sec)	MUF 3000 km (Mc/sec)	$f_{Es}$ (Mc/sec)
January...	326	215	218	423	312	294	2.84	4.11	4.66	0.71	13.0	....	....
February...	331	217	218	403	309	282	2.76	4.01	4.62	0.69	13.3	....	....
March.....	313	226	218	400	304	266	2.60	4.10	4.99	0.75	14.6	....	....
April.....	300	233	220	381	288	246	2.39	3.93	4.80	0.76	14.5	....	....
May.....	293	236	224	366	280	239	2.52	3.99	4.21	0.71	13.0	....	....
June.....	294	230	226	365	283	240	2.41	3.93	4.12	0.77	12.7	....	....
July.....	297	223	220	362	275	239	2.41	3.89	3.85	0.79	....	12.8	3.0
August.....	....	....	213	....	289	253	2.59	4.01	4.31	0.79	....	14.0	2.9
September.	....	....	215	....	297	258	2.49	4.10	4.75	0.87	....	15.2	2.9
October...	....	....	217	....	318	276	2.67	4.27	5.17	0.87	....	15.9	3.2
November.	....	....	218	....	316	275	2.82	4.33	5.71	0.88	....	17.4	3.8
December.	....	....	226	....	340	302	2.95	4.34	5.59	0.90	....	16.3	4.3

TABLE 8

RAINFALL AT WATHEROO MAGNETIC OBSERVATORY  
DURING 1944

Month	Monthly total (in.)	No. days	Average for 27 years (in.)
January.....	0.01	1	0.36
February.....	0.00	0	0.52
March.....	0.48	2	1.04
April.....	0.34	4	0.90
May.....	2.49	11	2.20
June.....	1.40	10	3.30
July.....	4.37	15	2.91
August.....	1.94	10	2.18
September.....	0.58	12	1.25
October.....	0.14	3	0.80
November.....	0.17	4	0.30
December.....	0.36	6	0.41
Totals.....	12.28	78	16.17

**Junior Observer.** A. Parkes was appointed as Junior Observer in May 1945. The services of one technical assistant and one clerk were made available by the Royal Australian Air Force. Two mechanics and a yardman were employed for the greater part of the report-year.

Grateful acknowledgment is made to the Department of Air for assistance with personnel and for courtesy in undertaking the transmission of records and data between Melbourne and Washington; the Commonwealth Department of Trade and Customs continued assistance in according free entry of supplies and equipment.

All members of the staff were enthusiastic and efficient, in spite of great difficulties, in coping with the ever increasing volume of work, and they have successfully completed another year's accumulation of valuable geophysical data.

**Huancayo Magnetic Observatory.** The Huancayo Magnetic Observatory is situated in the central valley of the Peruvian Andes about  $8\frac{1}{2}$  miles west of the town of Huancayo at an altitude of 3350 meters (11,000 feet) above sea-level, and in latitude  $12^{\circ} 02'7$  south and longitude  $75^{\circ} 20'4$  west of Greenwich.

Automatic recording equipment functioned throughout the year to produce continuous records of the following geophysical phenomena: (1) horizontal intensity, vertical intensity, and declination of the Earth's magnetic field; (2) atmospheric potential-gradient; (3) positive and negative conduc-

tivity of the air; (4) earth-current voltages between four pairs of geographically oriented earthed electrodes; (5) cosmic-ray radiation; (6) seismic movements in the east-west, north-south, and vertical directions; (7) heights and densities of the ionospheric regions in the Earth's upper atmosphere; and (8) barometric pressure, temperature and humidity of the air, velocity and direction of wind, and hours of sunshine. In addition, field-intensities were recorded during the last

the annual changes from 1943.5 to 1944.5 as determined from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination,  $-5.2'$ ; horizontal intensity,  $-33$  gammas; vertical intensity,  $-11$  gammas; inclination,  $-1.2'$  (see table 1 for mean annual values). Table 9 summarizes the mean monthly scale-values for the magnetographs.

TABLE 9

## SCALE-VALUES OF MAGNETOGRAPHS, HUANCAYO MAGNETIC OBSERVATORY, 1944

MONTH	ESCHENHAGEN			LA COUR	
	<i>D</i> ('/mm)	<i>H</i> (reduced to base- line) ( $\gamma$ /mm)	<i>Z</i> (means of daily values) ( $\gamma$ /mm)	<i>H</i> ( $\gamma$ /mm)	<i>Z</i> ( $\gamma$ /mm)
January.....	0.988	1.98	4.15	6.15	8.20
February.....	0.984	1.96	4.06*	6.23	8.34
March.....	0.986	1.97	4.07	6.10	8.48
April.....	0.984	1.97	4.09	6.17	7.92
May.....	0.986	1.97	4.13	6.39	7.54
June.....	0.992	1.96	4.14	6.12	7.77
July.....	0.985	1.96	4.26*	6.28	7.87
August.....	0.982	1.95	4.38	6.26	7.46
September.....	0.984	1.95	4.31*	6.26	7.46
October.....	0.983	1.96	4.31	5.68	7.92
November.....	0.982	1.95	4.35	6.06	7.85
December.....	0.984	1.95	4.34	5.62	8.00

\* Mean value over several base-line shifts.

two and a half months of the report-year for four selected high-frequency radio stations far distant from the Observatory.

Daily observations were made of the activity in the Sun's atmosphere (with the Hale spectrohelioscope), of nuclei-counts in the air, barometric pressure, humidity of the air, and maximum and minimum temperatures of the air.

Scale-value and base-line observations for the Eschenhagen magnetographs were made regularly as in other years, and monthly scale-values observed for the la Cour rapid-run magnetograph. The preliminary values for

Weekly calibration-observations were made for records of potential-gradient and atmospheric conductivity; the potential-gradient reduction-factor was determined quarterly by comparisons with potentials measured on a near-by standardization plot. The preliminary mean values of the atmospheric-electric elements are shown in table 10.

Rainfall for the year was 32.00 inches, about 3 inches over the 23-year average of 29.21 inches. The maximum temperature for the year was  $24.4^{\circ}$  C in November 1944, and the maximum monthly mean was  $21.9^{\circ}$  C, also in November 1944. The minimum

TABLE 10

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
HUANCAYO MAGNETIC OBSERVATORY, 1944

MONTH	No. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU			
		Reduction- factor	Value* (V/m)	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January.....	1	....	52.2	3.72	3.53	7.25	1.05
February.....	1	1.14	46.8	3.58	3.69	7.27	0.97
March.....	2	....	73.4	3.36	2.84	6.20	1.18
April.....	6	....	54.1	3.27	3.12	6.39	1.05
May.....	6	1.22	55.8	3.95	4.08	8.03	0.97
June.....	8	....	44.9	4.28	4.37	8.65	0.98
July.....	8	....	45.1	3.62	4.14	7.76	0.87
August.....	8	1.16	55.8	2.37	2.57	4.94	0.92
September.....	5	....	42.3	3.87	4.44	8.31	0.87
October.....	5	....	59.6	4.04	4.20	8.24	0.96
November.....	4	1.16	53.6	4.44	4.75	9.19	0.93
December.....	3	....	42.5	4.15	4.96	9.11	0.84
Totals and means .....	57	1.17	52.2	3.72	3.89	7.61	0.97

\* Using reduction-factor 1.15.

TABLE 11

MONTHLY MEAN METEOROLOGICAL ELEMENTS, HUANCAYO MAGNETIC OBSERVATORY,  
1944, AND CORRESPONDING 23-YEAR MONTHLY MEANS, 1922-1944

MONTH	TOTAL RAINFALL		MAXIMUM TEMPERATURES		MINIMUM TEMPERATURES	
	1944 (in.)	23 years (in.)	1944 (°C)	23 years (°C)	1944 (°C)	23 years (°C)
January.....	7.30	4.97	17.74	18.65	5.82	6.96
February.....	5.44	4.28	16.83	18.23	5.99	6.96
March.....	5.38	4.46	17.17	18.17	5.75	6.46
April.....	1.96	2.07	18.43	18.86	4.38	5.01
May.....	0.90	1.16	18.81	19.34	2.23	3.02
June.....	0.06	0.40	19.25	19.01	-1.42	1.76
July.....	0.01	0.30	19.09	18.93	-0.27	0.67
August.....	0.02	0.68	20.13	19.57	1.30	2.57
September.....	1.61	2.08	19.18	19.58	3.12	5.18
October.....	3.43	2.51	19.83	20.18	5.70	5.80
November.....	1.45	2.76	21.91	20.61	4.10	5.94
December.....	4.44	3.54	18.71	19.70	5.47	6.38
Totals and means .....	32.00	29.21	18.92	19.24	3.51	4.73

for the year was  $-8.6^{\circ}$  C in June 1944, and the lowest monthly mean minimum was  $-1.42^{\circ}$  C in June (an all-time low for monthly mean minima in 23 years). In table 11 are shown the monthly rainfall, monthly mean minimum, and monthly mean maximum temperatures for the calendar year

mic disturbances was reported in this manner. All monthly magnetic, ionospheric, and (recently) field-intensity data were completed in the first or second day of the following month and sent by air express to the Department in Washington. Monthly résumés of meteorological data were supplied to the

TABLE 12

PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,  
HUANCAYO MAGNETIC OBSERVATORY, 1944

75° west meridian time (h)	$h_{F_1}^{max*}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max*}$ (km)	$h_{F_2}^{min}$ (km)	$f_E^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)	$f_{Es}^t$ (Mc/sec)	MUF $\ddagger$ 3000 km (Mc/sec)
00.....	...	...	293	259	....	....	5.02	....	....	15.45
01.....	...	...	285	254	....	....	4.56	....	....	14.33
02.....	...	...	283	253	....	....	3.92	...	...	13.05
03.....	...	...	281	256	....	...	3.28	....	....	11.06
04.....	...	...	281	260	...	...	2.77	...	....	9.48
05.....	...	...	285	267	0.84	...	2.38	0.82	...	8.01
06.....	...	...	283	249	1.53	...	4.05	1.01	2.8	14.56
07.....	243	226	290	247	2.41	3.94	6.21	1.21	3.5	20.81
08.....	233	215	332	302	2.87	4.23	7.18	1.43	4.7	22.35
09.....	217	208	375	336	3.19	4.37	7.53	1.62	5.5	21.00
10.....	207	205	400	356	3.38	4.43	7.28	1.75	5.3	19.63
11.....	202	201	404	378	3.43	4.46	7.11	1.86	5.3	18.93
12.....	200	201	404	385	3.47	4.47	7.13	1.88	5.2	18.68
13.....	201	199	398	373	3.50	4.44	7.29	1.87	5.4	19.01
14.....	201	199	383	356	3.32	4.37	7.54	1.81	5.0	19.83
15.....	211	200	374	333	3.03	4.25	7.85	1.67	4.9	20.75
16.....	235	207	333	285	2.72	4.11	7.97	1.45	4.4	21.38
17.....	205	..	340	252	2.23	....	7.98	1.22	3.2	21.88
18.....	...	...	350	257	1.28	....	7.84	1.01	3.6	22.36
19.....	...	...	356	277	....	....	7.27	0.94	....	20.96
20.....	...	...	344	276	....	....	6.88	...	....	19.93
21.....	...	...	323	266	...	...	6.57	....	....	19.71
22.....	...	...	307	262	...	...	6.20	....	....	19.01
23.....	...	...	300	263	...	...	5.63	....	....	17.11

\* January to June only.

† July to December only (median values).

‡ July to December only.

1944, as compared with the means for 23 years.

Scaling of traces and reduction of data were kept current and no effort was spared to keep all instrumental equipment in repair and proper adjustment for the production of dependable records. The weekly broadcasts of magnetic and seismological data were made throughout the year; a total of 26 seis-

Dirección General de Comunicaciones y Meteorología Aeronáutica in Lima and to the Huancayo military authorities, and in addition a number of special compilations of meteorological and magnetic data were supplied to local and other institutions and persons upon request.

The ionospheric data obtained during 1944 are summarized in tables 12 and 13.

The new Ionospheric Laboratory, which was begun in May 1944, was completed in November and the ionospheric equipment removed from its former position to the new building. The new Laboratory houses the radio field-intensity equipment, whose installation was begun in February 1945. New alternating-current converters for these equipments were installed in the power-plant and an underground conduit was laid for power-lines to the building. The necessary antenna

hauled, checked, and adjusted the seismological equipment, with the assistance of members of the Observatory's staff. During April 26-28, Observer William Wiles of the Magnetic Section of the United States Coast and Geodetic Survey, accompanied by Commander O. L. Rivera of the Peruvian Hydrographic Office and Colonel Pedro A. Delgado of the Geographical Institute of the Peruvian Army, made a study of the correlation between diurnal-variation observations made at

TABLE 13

PRELIMINARY MEAN MONTHLY VALUES OF IONOSPHERIC DATA,  
HUANCAYO MAGNETIC OBSERVATORY, 1944

Month	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	$f_E^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)	$f_{Es}$ (Mc/sec)	MUF 3000 km (Mc/sec)
January....	220	208	362	311	2.67	4.32	6.15	1.34	†	†
February....	214	204	331	289	2.66	4.28	6.19	1.46	....	....
March....	222	213	343	282	2.59	4.36	7.28	1.46	....	....
April....	216	206	329	274	2.45	4.32	6.55	1.29	....	....
May....	214	206	322	285	2.39	4.16	5.27	1.15	....	....
June....	210	201	327	293	2.50	4.12	4.87	1.16	....	....
July....	*	201	*	299	2.53	4.09	4.81	1.22	4.50	14.01
August....	...	201	...	298	2.32	4.27	5.49	1.81	4.80	15.84
September..	...	204	...	285	2.41	4.39	6.36	1.74	4.45	18.34
October....	...	205	...	282	2.52	4.55	7.32	1.75	5.50	20.79
November..	...	206	...	295	2.42	4.55	7.56	1.86	4.65	21.24
December..	...	208	...	311	2.56	4.63	7.19	1.75	5.40	20.35
Means or medians	216	205	336	292	2.50	4.34	6.25	1.50	4.88	18.43

\* Discontinued June 30, 1944.

† Begun July 1, 1944; values of  $f_{Es}$  are medians.

poles were erected and antennas installed for the field-intensity equipment.

S. Hluchan, of the temporary staff, was in residence at the Observatory, to assist in the installation and adjustment of the field-intensity recorders, from March 25 to June 11, 1945; he successfully completed a heavy schedule of installation, operational tests, and observations. F. P. Ulrich, Chief of the seismological field-survey of the United States Coast and Geodetic Survey, was at the Observatory between April 7 and 10 with two Peruvian observers from Lima. He over-

stations in the north of Peru and records at the Observatory on the days of field-observation.

No changes in the staff took place during the year. Paul G. Ledit continued as Observer-in-Charge, except for absence on official business and vacation in the United States for over three months early in 1945; Mark W. Jones was in charge during the period of his absence. Jones left early in June for three months on official business and vacation in the United States. A. A. Giesecke, Jr., and E. J. Chernosky continued as resident ob-

servers, and T. Astete, V. Murga, and E. Melgar as clerical assistants. The efficient and wholehearted assistance given by all these men made possible the heavy program of scientific work as well as the construction of the new Laboratory and the installation in it of the ionospheric and field-intensity equipment.

Grateful appreciation is hereby expressed for the continuing assistance of the United States Embassy in obtaining free entry for shipments of equipment and supplies, and in providing priorities for monthly air-express shipments of data. It is also a pleasure to acknowledge with thanks the many courtesies extended to the Observatory and its personnel by the Peruvian government and its officials, as well as by many Peruvian individuals who have gone out of their way to show their friendliness.

*College Observatory, Alaska.* The College Observatory is located at the University of Alaska in the zone of maximum auroral activity, about 5 miles by road west of Fairbanks, in latitude  $64^{\circ} 51.4'$  north, longitude  $147^{\circ} 49.3'$  west, at about 381 meters (1250 feet) above sea-level. It is operated by the Department in cooperation with the University of Alaska.

During July 1, 1944 to June 30, 1945, continuous records were maintained as follows: (1) three geomagnetic elements of declination, horizontal intensity, and vertical intensity; (2) rate of change of geomagnetic horizontal intensity; (3) height- and penetration-frequencies of the ionospheric regions; (4) electric field-strength of radio waves from selected high-frequency broadcasting stations in the United States, England, and Japan; (5) direction of arrival and instantaneous field-strength of high-frequency radio signals. During all or part of the year seismographs were operated for the United States Coast and Geodetic Survey and also solar-radiation measuring instruments for the United States Weather Bureau. Preliminary analyses of seismograms were completed at College; these and records of solar radiation were transmitted to the respective bureaus.

Adequate control-observations and standardizations for all instruments were maintained to assure reliability of the resulting data.

The la Cour magnetograph functioned without interruption. Reductions of the records were kept current. At weekly intervals *K*-index figures were telegraphed to the Washington office, and the reductions were forwarded monthly. Scale-values have differed little since installation, those for the year 1944 being  $5.2/\text{mm}$  for declination,  $18.37/\text{mm}$  for horizontal intensity, and  $27.07/\text{mm}$  for vertical intensity. The preliminary mean values for all days of the year 1944, as deduced from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination,  $+29^{\circ} 46.1'$ ; horizontal intensity,  $12587\gamma$ ; vertical intensity,  $+55395\gamma$ .

Ionospheric observations were made continuously and summaries of the results were cabled. Reductions and calibrations were kept current and transmitted monthly. Information on local propagation-conditions was furnished the Cold Weather Test Group at Ladd Field for use in evaluation of performance of emergency transmitters. Certain changes in interpretation of ionospheric records and in method of statistical reduction were made as a result of the International Radio Propagation Conference.

The ionospheric investigations during the year emphasized the desirability of continuing this work over at least one sunspot-cycle. Further attacks were made upon the relation between magnetic, auroral, and signal-intensity changes and ionospheric phenomena. It was demonstrated that fade-outs and sporadic *E*-layer phenomena occurred with greater intensity during periods of large magnetic disturbance, but that neither fade-outs nor sporadic *E*-layer ionization led the other in phase with onset of disturbance.

Seasonal and semiannual changes in height of maximum electron-density were found to occur systematically especially in *F*-

and  $F_1$ -layers, in agreement with corresponding changes at Huancayo and Watheroo.

Observations of direction of arrival of high-frequency radio signals were made by means of a Navy model spaced-loop direction-finder initially at hourly intervals and later at half-hourly intervals. Observations were made and recorded manually and transmitted at weekly intervals to Washington for analysis. Several aircraft were located and assisted to safe landings before the installation at Ladd Field in December of the Air Corps direction-finder unit. Preliminary analysis of some of the observations was undertaken at the Observatory as time permitted. The direction-finder conference in Washington, in February 1945, was attended by Seaton, and results of the work were discussed.

Direction-finder research clearly showed that a simple statistical approach to the problem of error-prediction is inadequate. By means of contours proportional to equal ion-densities from world-wide ionospheric data, success of 70 per cent was achieved in prediction of mean direction of wave-deviation. These predictions were made on the basis of calculated horizontal refraction from gradient-vectors developed from ionization-contours. Approaches to solution of the problem from the standpoint of ionospheric tilt are being undertaken.

Operation of the horizontal-intensity fluxmeter was essentially continuous until May 1945, when the buried coil-system again failed, apparently because of leakage of water into the coils resulting in low-resistance grounding of the conductors together with generation of local potentials by chemical action. The instrument, therefore, is out of service until repairs can be completed. Reports giving summaries of instrumental constants and reduction of the four largest variations for each month were transmitted at the end of each month.

The four signal-intensity recorders functioned without interruption. At the close of the year Station GSD, in England, was still being recorded, completing a four-year series of measurements. During the year Station WWV, Washington, D. C., was substituted

for German and American stations and gave satisfactory results except for occasional interference. San Francisco, KGEX/KGEI, has been recorded for a year, thus furnishing a moderately long series of continuous measurements on this location. The remaining recorder has been used principally for east coast United States stations, but the results are not satisfactory because of adverse beam-directions at the transmitters. Measurements of field-strength of emergency transmitters were carried out for the Cold Weather Test Group at Ladd Field. Reductions to tabular quantities were kept current at the Observatory and forwarded at monthly intervals to the Department.

The recording with the automatic auroral camera was discontinued pending repairs at Washington during the season of 1944-1945. Analysis of the second half of the observational series obtained in the 1943-1944 season was completed.

The second part of the auroral studies for the season of 1943-1944 was completed, and in general substantiated the results of the first part. There is clearly a lack of detailed correspondence between ionospheric phenomena and visible zenith-aurora, although the gross correlation continued to be present. Beyond doubt, more refined methods of investigation are indicated for future study of the problem.

During the year the University of Alaska has continued its splendid cooperation with the Department, making available three laboratories and two offices in its main building as well as areas of the campus for additional installations. The University furnishes in addition heat, light, water, and general facilities, all without charge. Living quarters and garage space are made available at nominal charges to personnel. The active interest and support of President Bunnell and the Board of Regents has been of great benefit to successful prosecution of our work.

Some time was spent in forwarding the University's plan for establishment of a Geophysical Institute at the University to provide facilities for postwar research in the Arctic. If the plans for the Geophysical Institute

develop, provision will be made for inclusion of much of the present research-program being undertaken by the Department.

#### COOPERATION WITH OTHER OBSERVATORIES

*Cheltenham Magnetic Observatory, United States.* The cooperative program with the Cheltenham Observatory of the United States Coast and Geodetic Survey was continued, using CIW instruments for absolute stand-

*Apia Observatory, Western Samoa.* In the geomagnetic program CIW magnetometer 9 and CIW Schulze earth-inductor 2 were used for absolute observations. *K*-indices were supplied.

*Hermanus Magnetic Observatory, South Africa.* Dr. A. Ogg continued the use of CIW magnetometer-inductor 17 for absolute observations until early June, when the instrument was transferred, after comparisons,

TABLE 14  
PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
TUCSON MAGNETIC OBSERVATORY, 1944

MONTH	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
	No. selected days	Value* (V/m)	All complete days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+/\lambda_-)$
January . . . . .	26	62.2	23	2.17	1.93	4.10	1.12
February . . . . .	21	58.9	27	2.23	2.14	4.37	1.04
March . . . . .	23	72.7	30	1.98	1.84	3.82	1.08
April . . . . .	20	50.0	28	2.45	2.43	4.88	1.01
May . . . . .	22	59.9	31	2.52	2.45	4.97	1.03
June . . . . .	20	56.0	30	2.59	2.65	5.24	0.98
July . . . . .	20	51.0	27	2.47	2.35	4.82	1.05
August . . . . .	15	48.7	22	2.34	2.16	4.50	1.08
September . . . . .	16	51.2	23	2.45	2.27	4.72	1.08
October . . . . .	20	46.6	27	2.56	2.32	4.88	1.10
November . . . . .	15	60.8	29	2.07	1.77	3.84	1.17
December . . . . .	22	61.8	31	2.02	1.74	3.76	1.16
Totals and means . . . . .	240	56.6	328	2.32	2.17	4.49	1.08

\* Using reduction-factor 1.24.

ards in horizontal intensity and inclination. Automatic daily records of cosmic-ray intensity were continued with the CIW precision meter, through the courtesy of Observer-in-Charge J. Hershberger.

*Tucson Magnetic Observatory, United States.* Through cooperation with the United States Coast and Geodetic Survey, registrations of atmospheric potential-gradient and of positive and negative air-conductivities were obtained, with the assistance of Observer-in-Charge J. H. Nelson. Table 14 summarizes the monthly and annual values of the atmospheric-electric elements.

to the Elisabethville Magnetic Observatory in the Belgian Congo for use as standard there.

*Godhavn Observatory, Greenland.* K. Thiesen continued the magnetic and cosmic-ray programs. *K*-indices and magnetic reductions were received currently through the courtesy of the Secretary of State, Washington, D. C.

*Ivigtut Magnetic Observatory, Greenland.* Despite the hardships entailed in the operation of a magnetic observatory under severe climatic conditions, since the Observatory must necessarily be located at some distance

from the mine-workings, S. O. Corp, Manager of the Ivigtut Cryolite Mines, obtained complete magnetic records. The company generously donated facilities, electric power, and services of personnel. *K*-indices of geomagnetic activity were reported weekly through the cooperation of the United States Army Communication Services.

*Christchurch Observatory, New Zealand.* Director H. F. Baird continued the operation

of the CIW cosmic-ray meter. *K*-indices were regularly supplied.

*Royal Alfred Observatory, Mauritius.* CIW marine-inductor 4 continued on loan for determination of inclination at the Royal Alfred Observatory.

*Teoloyucan Observatory, Mexico.* Dr. J. Gallo, Director of the National Astronomical Observatory of Mexico, continued operation of the CIW cosmic-ray meter.

### PUBLICATIONS ON THE "CARNEGIE" DATA

It was decided to publish, as a final volume in the series "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under Command of Captain J. P. Ault," various discussions of the equipment and operating program of the *Carnegie*, and summaries of results and of difficulties encountered and needs of future work. Thus the complete series will consist of 13 volumes, including Biology I to V, Meteorology I and II, Oceanography IA, IB, and II to IV, and Chemistry I. The printing of Oceanography IB was completed, but delivery was not possible within the report-year because of delays in binding caused by the emergency.

The master-copies for offset printing of Oceanography III and IV were 75 per cent completed on June 30, 1945. Oceanography III is devoted to atmospheric-electric data obtained aboard the *Carnegie*, and discussions thereof. The several sections, following a preface by Fleming, are: Significance of atmospheric-electric observations at sea, by Gish; Instruments, observational procedure, and constants, by Torreson; Progress-reports, by Parkinson; Abstract of log; Tabulated data, in four parts, on daily observations of atmospheric-electric elements, diurnal variations, hourly-recorded potential-gradient, and hourly-recorded air-conductivities, all compiled by Torreson; and one section of

eight papers and studies by Gish, Torreson, and Wait.

The thirteenth and final volume, Oceanography IV, is entitled "Future magnetic, electric, and oceanographic surveys." It contains eight sections: The Captain's progress-reports, by Ault; Narrative of the cruise, by Paul; The magnetic work of the *Carnegie* and need for future ocean magnetic surveys, by Fleming; The *Carnegie*: its personnel, equipment, and work, by Moberg; Gravity-measurements on board the *Carnegie*, by Forbush; Note on fluorine content of ocean-bottom samples, by Shepherd; Suggestions for future magnetic, electric, and oceanographic surveys—a group of nine reports, by Peters, Torreson, Soule, Graham, and Seaton; Bibliography of publications relating to Cruise VII of the *Carnegie*, compiled by Mrs. R. M. Crow.

The thirteen volumes will have presented in detail the observational data obtained, together with full compilations of the results, and with considerable discussion and interpretation by the many investigators who have given so much time and enthusiastic support in the preparation of the volumes of the series. Naturally, there are many possibilities for additional discussions and classifications of data, particularly in the great mass of biological information acquired. It is felt, however, that further researches and compilations

and classification of data must be left to specialists in the various lines of endeavor, who now have available all the observational material and results with suitable notes regarding details for additional study.

Torreson, after return (January 1, 1945) from leave of absence on war research, was made responsible for additional studies and final editing of completed manuscripts for the last two volumes. As he was a member of the *Carnegie's* scientific staff during 1928-1929, his organization of the

material greatly advanced final preparation of the data and discussions for publication. Mrs. R. M. Crow has been responsible for transcribing all copy into a form suitable for offset printing, has prepared the layout of each volume, assembled and prepared bibliographical material, and in many other important ways has contributed to the completion of the memoirs of the *Carnegie's* last cruise. Preparation of drawings and other illustrations was by Hendrix and Green.

### INSTRUMENT-SHOP

The work of the Instrument-Shop and the Cyclotron Shop during the report-year totaled approximately 33,600 hours, of which 6900 hours were devoted to the construction, maintenance, and operation of the cyclotron, and 26,700 hours to instrumental work. Approximately 22,000 hours of the latter involved war contracts, the remaining 4700 hours being used for construction of new equipment and experimental apparatus, repairs and improvements to instruments and apparatus, buildings, and grounds, and miscellaneous items. The time for contractual obligations included 3174 hours' overtime.

A large portion of the work of the shop

other than for contracts involved replacement parts for ionospheric and anemographic apparatuses at Watheroo, Huancayo, and College observatories. Minor repairs and modifications were made to several magnetometers and inductors, ion-counter, and ionization-chambers. All laboratory benches and cabinets for the Cyclotron Building were completed except those required in four rooms.

The time of the woodworking shop was devoted to packing and shipping of equipment and supplies for contracts and requisitions, and to construction in, and minor repairs to, all buildings at Washington and Kensington.

### MISCELLANEOUS ACTIVITIES

There was active participation in scientific meetings, conferences, and organizations by members of the staff, of whom many served as officers and on special committees. So far as possible, contacts were maintained with geophysical organizations and geophysicists abroad and in the United States. Many activities related to aspects of the war effort, and to conferences with cooperating observatories, organizations, and individuals in the United States, Canada, and Australia.

Besides the papers and reports noted

above and in the bibliography following, lectures were delivered as follows: "Structure elements of quasigroups, III," by Duffin and Pate, American Mathematical Society, Wellesley, Massachusetts, August 1944; "General historical development of ionospheric research in United States with particular reference to recent developments," by Wells, Australian Radio Propagation Committee of Radio Research Board, East Melbourne, Australia, December 1944; "The geographic distribution of aurora," by Vestine, Philosophical Society,

Washington, D. C., February 1945; "The odograph," by McNish, *Philosophical Society, Washington, D. C.*, February 1945.

*Library.* Although the war in Europe came to a close in the latter part of the report-year, there resulted no appreciable change in the international situation with regard to foreign scientific books and journals. Although reports have been received indicating a reawakening of scientific activity and publication in France and Belgium, postal restrictions have not been sufficiently lifted to permit procurement of publications from those countries. The principal scientific journals of Great Britain and the Union of Socialist Soviet Republics continue to be received. In the case of domestic periodicals, there is still a dearth of original contributions on terrestrial magnetism and electricity, attributable in large measure to the number of investigators engaged in activities bearing on the war and, to some extent, to the fact that certain researches, already completed, may not yet be made public.

The number of accessions during the year was 415 and the total number of books and pamphlets accessioned on June 30, 1945 was 27,955. The practice adopted in the past of cataloguing all articles in current publications of interest in connection with the investigational work of the Department was continued, thus assuring ready reference to material in the Library not otherwise easily located.

Librarian Harradon continued as co-editor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, giving attention particularly to foreign contributions, preparation of notes, reviews of books and reports, and the compilation of the annotated bibliographies of recent publications on cosmic and terrestrial magnetism and electricity published regularly in that journal. He also continued as

Secretary of the Section of Meteorology of the American Geophysical Union.

In continuance of the project of making available in modern English outstanding contributions to the early history of geomagnetism, referred to in previous reports, two additional contributions, provided with suitable introductions, were prepared and published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. These are "Extracts on magnetic observations from log-books of João de Castro 1538-1539 and 1541," and "The haven-finding art," by Simon Stevinus.

The list of publications by members of the Department on December 31, 1944 showed a total of 2302. Because of the continued priorities given work connected with the war and the restrictions on mail to foreign countries, only a partial distribution of accumulated reprints could be effected. Complete distribution must be deferred until some future time.

The facilities of the Library were made available to investigators from universities and various bureaus of the government, and particularly to specialists concerned with research-problems related to the war. Interlibrary loans were continued. Information on a wide range of subjects, some of which only remotely related to the work of the Department, was supplied in response to inquiries from numerous sources. Cordial relations were maintained with other libraries and in particular the Library of Congress.

Dove continued as Secretary to the Director and remained in charge of the general correspondence files and the storage and distribution of reprints. He typed many reports and manuscripts and gave much assistance in proofreading.

*Office administration.* The work of the staff assigned to the Administrative Assistant again was concerned almost entirely

with the war contracts of the Department, and related to correspondence, liaison with various departments of the government concerned, orders, accounts, and personnel.

A conference was held with Dr. Annand, Chief of the Bureau of Entomology and Plant Quarantine, and his assistants Drs. Dove and Rohwer, regarding tests to be made with DDT and mosquito repellants at our station in northern Canada, and by the Hudson's Bay Company at its posts in Canada.

Moats, Miss Gottshall, and Miss Dermody of the regular staff, and the many temporary employees assigned to the Administrative Assistant, gave faithful and efficient assistance, without which it would

not have been possible to accomplish the large amount of work done during the past year.

The many details of wartime shipments, inventories, statements of time and costs of work, preparation of reports and manuscripts, and secretarial work for the Director were completed by Capello and Dove. Charts, diagrams, and illustrations for many special reports and publications were prepared by Hendrix, who with J. W. Green also did much necessary photographic work. Filing and arranging of field-records were done by Miss Balsam, who with Capello maintained the catalogues of photographs and films, and index-albums of prints.

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#### SPECIAL PUBLICATIONS

Scientific results of cruise VII of the *Carnegie* during 1928-1929, under command of Captain J. P. Ault:

*Biology—V.* The genus *Ceratium* in the Pacific and North Atlantic oceans. By H. W. Graham and N. Bronikovsky. *Carnegie Inst. Wash. Pub.* 565, vii + 209 pp., 27 figs., 54 charts (1944).

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## SPECIAL PROJECTS: TERRESTRIAL SCIENCES

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1944 to June 1945.* (For previous reports<sup>1</sup> see Year Books Nos. 32 to 43.)

The end of World War II will make possible resumption of the active discussion and interpretation of accumulated data by the several groups of investigators who have cooperated with the Carnegie Institution of Washington in the Committee's program. The absorption of so many cosmic-ray students in war problems again seriously curtailed progress in discussions under way, as indicated in earlier reports.

The programs of the groups at the Bartol Foundation, the California Institute of Technology, the Massachusetts Institute of Technology, and the University of California may be resumed during the coming year. Brief reports for the year ended June 30, 1945 have been received from the men in charge of groups at Fordham University, New York University, the University of Chicago, and the Department of Terrestrial Magnetism. These reports, as appended, show good progress. Dr. Korff, of New York University, reports on research on counters, on measurements of neutrons produced by cosmic radiation, and on construction of a narrow-angle wide-aperture cosmic-ray telescope. Dr. Hess, of Fordham University, details measurements and interpretations of studies of atmospheric ionization. Mr. Forbush and Miss Lange, of the Department of Terrestrial Magnetism, report on routine handling of records. Professor Schein, of the group at the University of Chicago, reports on research on intermediate particles and on mesotron production in the stratosphere.

<sup>1</sup> For statement on formation, purposes, and policies of the Committee see Year Book No. 38 (1938-1939), pp. 335-349.

In spite of difficulties occasioned by the emergency of the war, it has been possible to continue with only minor interruption the cosmic-ray recordings at Cheltenham, Huancayo, Teoloyucan, Christchurch, and Godhavn. The desideratum of continuous and homogeneous series of data at world-wide and well distributed stations has been realized since 1936 or 1937 for four of the stations and since 1938 for Godhavn. Thus by 1949 or 1950 the records will include at least a complete sunspot-cycle for all five stations. This mass of material should be ample for statistical analyses concerning possible seasonal effects in different localities, solar-day, lunar-day, and sidereal variations, day-to-day changes, world-wide changes, geomagnetic correlations, etc. These analyses, together with data on the higher atmosphere resulting from numerous determinations above different points on the Earth's surface and parallel coordinated researches in the laboratory, will certainly improve understanding and interpretation of cosmic radiation.

A request has been received from Professor Amadore Cobas, head of the Department of Physics of the University of Puerto Rico, for the loan of a meter to record near San Juan. It may be recalled that the region of Puerto Rico was one considered at the beginning of the Committee's program; the station at Teoloyucan, Mexico, in about the same geographic and geomagnetic latitudes, was then selected instead of Puerto Rico. Because of the apparently somewhat anomalous data recorded at Teoloyucan, it is desirable, if possible, to provide equipment for Puerto Rico. The Committee is now considering

this matter. No other applications for grants or loans of equipment have been received.

Grateful acknowledgment must again be made to the directors and members of organizations which continued contributions of services and laboratories. Those so aiding the program are: the Danish Meteorological Institute; the National Astronomical Observatory of Mexico; the New Zealand Department of Scientific and Industrial Research; and the United States Coast and Geodetic Survey. The forwarding of supplies for maintenance of the station at Godhavn has been aided by the Consul-General of Denmark in New York and the United States Coast Guard.

W. S. ADAMS  
J. A. FLEMING, *Chairman*  
F. E. WRIGHT

STATISTICAL INVESTIGATIONS OF COSMIC-RAY  
VARIATIONS AT DEPARTMENT OF  
TERRESTRIAL MAGNETISM

S. E. FORBUSH AND ISABELLE LANGE

*Instruments.* The precision cosmic-ray meters of the Carnegie Institution of Washington were continuously operated at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-1, John Hershberger in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, meter C-2, P. G. Ledig in charge; National Astronomical Observatory of Mexico at Teoloyucan (D. F., Mexico), meter C-4, Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, meter C-5, J. W. Beagley in charge; Godhavn (Greenland)

Magnetic Observatory of the Danish Meteorological Institute, meter C-6, K. Thiesen in charge.

*Reduction of data.* Owing to pressure of war work it was not possible to keep current the tabulations of hourly values of cosmic-ray ionization, bursts, and barometric pressure.

War work engaged the full time of Miss Lange and Mr. Forbush and permitted only the routine handling of records and assistance in the maintenance of meter C-1 at Cheltenham. Of the Institution's five cosmic-ray meters at the above stations, four have been in operation since the middle of 1936 or before. This continuous series of data, covering nearly a complete sunspot-cycle, should, on analysis, provide a better basis for interpreting the causes for the correlations between changes in cosmic-ray intensity and those in the Earth's external magnetic field.

STUDIES OF ATMOSPHERIC IONIZATION AT  
FORDHAM UNIVERSITY

VICTOR F. HESS

Measurements with the improved type of Gish-Hess ionization-meter, constructed by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, were made in the summer and fall of 1944 and in the spring of 1945. They were made on a wooden pier 80 meters offshore in New York, at Spray Beach (New Jersey), and at different localities in the suburbs of New York. These measurements are being continued and a complete report will be prepared later.

A special study of the effect of evacuating and refilling of the ionization-vessels with dry, filtered nitrogen was made, and it was found that a small initial drop in ionization by 0.5 to 1.0  $I$  after refilling is due to a temporary removal of a gas-

layer from the walls. It takes several days—up to 10—to re-establish the normal ionization in the chambers.

Plotting the ionization ( $q$ ) against ratio of surface to volume of each chamber ( $A/W$ ) gives a straight line, the intercept of which with the ordinate of ionization allows one to deduce the actual ionization without the wall-effect.

A similar procedure was adopted for the determination of Eve's constant ( $K$  = number of ion-pairs produced by 1 gram of radium per cc and sec at unit-distance) with all three chambers. The smallest chamber shows the largest value of  $K$ . The results as graphed show that  $K$  has a linear relation to ( $A/W$ ), and extrapolation for ( $A/W$ ) = 0 gives the value of  $K$  for the free atmosphere as  $4.6 \times 10^9$  ion-pairs per gram radium, per cc and sec in nitrogen at normal temperature and pressure—in fairly good agreement with other methods. This new method of determining  $K$  was reported at the annual meeting of the American Geophysical Union on May 31, 1945, by V. F. Hess and Eva Balling.

The new ionization-meter is also very useful in determining the radium content of the human body by its gamma-ray effect. In the radium industry technicians and workers sometimes acquire a certain permanent contamination with radium amounting to several micrograms of radium. The Gish-Hess meter, when calibrated with a 1-microgram radium standard preparation at different distances within a "water-phantom" of the human body, allows detection of 0.2 microgram of radium. This instrument therefore will be helpful in detecting incipient radium poisoning in workers and in studying the changes with time in the radium burden of individuals.

#### COSMIC-RAY RESEARCH AT NEW YORK UNIVERSITY

S. A. KORFF

During the year July 1, 1944 to June 30, 1945, it was found possible to carry on some cosmic-ray research at New York University, in spite of the heavy demands which the war effort placed on the time of all persons concerned. The investigations described below were supported in part by funds administered by the Carnegie Institution of Washington.

*Research on counters.* The study of the properties of Geiger counters, described in previous reports, was continued. Some experiments were undertaken to determine whether any design could be devised which would reduce the operating potential and at the same time provide an arrangement capable of obtaining coincidence-counts. A new type of counter employing a grid surrounding the central wire was developed. The central wire had a glass bead at its center. It was found that the unit operated as two separate counters within the same outer envelope. The two sections of the counter separated by the bead discharged independently, and, in addition, counts of double height were observed when the two sections discharged simultaneously. The effect of adding the grid around the central wire was to reduce the operating potential. Experiments showed that considerable economies in operating voltage were attainable by this arrangement. For example, a counter which required 1500 volts in the absence of a grid would operate successfully on about 800 when equipped with the additional electrode. This development promises to be of considerable value in those counters in which high operating potentials are a distinct drawback. The combination of the bead on the central wire and the grid is a new contribution to counter-technique.

*Measurements of neutrons produced by cosmic radiation.* The study of the neutron component of the cosmic radiation was continued. A new device was built, consisting of a neutron-counter and adjustable cadmium and boron shields. The shields were automatically slipped over the counter and then removed at predetermined time-intervals by a small electric motor. The apparatus is at present undergoing tests. It is planned to adapt this instrument to high-altitude work.

*Construction of a narrow-angle wide-aperture cosmic-ray telescope.* In previous reports we have described theoretical calculations which we have made which permit new information about the production-levels and lifetime of the mesotron to be inferred from a study of the vertical cosmic-ray intensity at sea-level and the meteorological variables in the column of air above the instrument. The device for the experimental test of the predictions is now under construction. For this purpose, a narrow-angle, wide-aperture cosmic-ray telescope is being built. This telescope will employ a large number of counters which use a bead at the center of the wire, and thus provide a coincidence-device within a single envelope. The vertical intensity of the cosmic radiation will be measured with this telescope, at the same time that the meteorological data are obtained from near-by radiosondes. This device will next be used to determine the angular distribution and thus provide the data necessary to interpret the results obtained with the large Millikan and Compton meters which integrate the intensity received from all directions.

*Personnel.* K. Kupferberg and F. Reines carried out the theoretical analysis of the correlations between cosmic radiation and meteorological variables. A. Krumbein is constructing the vertical telescope. Dr. B.

Hamermesh is assisting with the work on neutron-counters.

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#### COSMIC-RAY RESEARCH AT THE UNIVERSITY OF CHICAGO

MARCEL SCHEIN

*Intermediate particles.* New investigations are now in progress to obtain additional evidence for the existence of mesotrons with a mass smaller than 200 electronic masses. For this purpose a special magnet-cloud-chamber apparatus has been constructed by Marcel Schein and A. J. Hartzler. By means of electronic circuits, the expansion of this chamber is controlled either by the passage of a cosmic-ray particle or by the injection of electrons into a large induction accelerator (betatron). The results of these investigations will be published later.

*Mesotron production in the stratosphere.* The balloon experiments on the production of mesotrons in paraffin and lead were continued by Marcel Schein, William G. Stroud, Jr., and F. Allen. The apparatus consisted of a number of counter-telescopes registering the simultaneous passage of several cosmic-ray particles through the paraffin or lead. Some of these outfits had an over-all weight of more than 60 pounds. Hence a larger number of balloons (45) had to be used to lift them into the stratosphere. The results of these experiments show that multiple mesotrons, or so-called mesotron showers, are abundantly produced by the impact of primary cosmic-ray particles (protons) upon atomic nuclei.

This process takes place, predominantly, close to the top of the atmosphere. The cross-section for mesotron production in paraffin was measured and found to be  $10^{-24}$  cm<sup>2</sup> (per nucleus). The mesotrons produced are knocked out in the forward direction with an average angular spread of 9° to 20°. The frequency of these processes as a function of atmospheric pressure approximately follows an exponential law, indicating that the mesotron showers in paraffin are produced rather in a single act than by successive impacts as assumed by Hamilton, Heitler, and Peng.

Results of a similar nature were obtained in lead. The number of mesotron showers found below a lead thickness of 18 cm was very abundant at high altitudes. A detailed analysis of these results is now in progress.

A simplified theory of cosmic-ray phenomena at high altitudes was worked out by I. Bloch. Starting with the idea of primary protons, the production and absorption of mesotrons was calculated as a function of altitude and latitude. The theoretical results were compared with the experimental data on the intensity of the hard component and the production of mesotrons in the stratosphere. This comparison strongly indicates that the multiplicity of mesotron production is 9 for primaries of an energy higher than  $7 \times 10^9$

electron-volts. For lower energies the multiplicity decreases with energy. To account for the large number of electrons present at the very high altitudes, it was assumed that in addition to mesotrons of the usual type there exist intermediate particles of extremely low stability (with a mean life of about  $10^{-9}$  second). These particles should then decay into electrons and neutrinos close to the point of their creation, giving rise to the high-altitude soft component.

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## DIVISION OF PLANT BIOLOGY

*Central Laboratory located at Stanford University, California*

H. A. SPOEHR, *Chairman*

Two major research projects which were prompted primarily by the desire to make a contribution to the war effort have taken the entire attention of the staff during the past year. One of these projects is concerned with the isolation from plant sources of material showing antibiotic properties. This material was first isolated from cultures of the unicellular green alga *Chlorella*, and was designated by the name chlorellin. The relatively small yields of antibiotic material originally obtained from the culture solutions have been greatly increased by the development of methods which made possible the direct extraction of the plant cells. By this means sufficient material was obtained for preliminary examination of the chemical nature of the material showing antibiotic properties. It has been found that these properties are due to or are associated with the presence of unsaturated fatty acids in the material extracted from the *Chlorella* cells. More important is the fact that the unsaturated fatty acids as first extracted from the fresh cells show very little or no antibiotic activity. This activity develops on exposure of the mixture of unsaturated fatty acids to air and light and involves a complex oxidation reaction.

Pure, authentic preparations of a number of unsaturated fatty acids have been found to show the same behavior; namely, they exhibit no antibiotic activity until after they have been exposed to air and light. After such treatment their antibiotic activity is of about the same magnitude as that of preparations obtained from *Chlorella* cells. In extension of these findings, a number of common food and fodder

plants have been examined and have yielded material which, after exposure to air and light, exhibits antibiotic properties similar to those derived from *Chlorella* cells. It appears, therefore, that this phenomenon, associated with unsaturated fatty acids, is of rather widespread occurrence and that it may have extensive significance, although there remains much to be worked out regarding the exact nature of the substances and chemical reactions which are involved in the production of this antibiotic.

The other research project prompted by the war has as its aim the development of improved range grasses for the West by employing newly discovered principles. For this purpose the attempt has been made to produce fertile, nonsegregating hybrids that would be unusually adaptable by employing as parents species from radically unlike environments. The bluegrasses, of the genus *Poa*, have met the requirements, because many of the species reproduce principally by seed developed asexually, so that most of their offspring are entirely maternal in their inheritance. The occasional sexually produced seedling can be a hybrid, in turn producing a preponderance of offspring just like itself. Thus in a single generation a new, highly constant form is potentially available.

Hybrids of promise have been obtained, for example, between Big bluegrass from the prairies of eastern Washington and a hardy race of Kentucky bluegrass from Swedish Lapland. In this instance the parents belong to different taxonomic sections of the genus, and were thought to be impossible to cross. These hybrids combine

the heredities of parents adapted to widely different climatic conditions, and also represent the combination of a bunch grass with a rhizome grass, and of a summer-active, winter-dormant species with a summer-dormant, winter-active one. From such materials it is hoped to discover types that will be better suited to environments in which the parents cannot thrive, and that will produce more feed by a better utilization of the soil and the growing season.

Many of the more promising hybrids and their parents are being tested at the Institution's two mountain stations as well as at the gardens of the central laboratory. Some are now being delivered to the Soil Conservation Service for the more extensive final testing of their potentialities.

The strictly practical aspects of the grass-breeding program have been in the nature of a demonstration of the applicability of principles recently discovered. The further production of such hybrids will

eventually be the function of other agencies concerned with grazing and land use. The program is also yielding scientific results of importance, as it is complementary to previous studies on the evolution and organization of the higher plants.

The extensive investigations of desert vegetation which have been carried on for many years by Dr. Forrest Shreve with several collaborators have been terminated with Dr. Shreve's retirement. A considerable part of this work has already been prepared for publication, and it is planned to complete this task within the next year. Owing to difficulties of carrying on field work and the fact that Dr. Chaney has been on special appointment in connection with the war, the investigations in paleobotany have been considerably curtailed during the past year. Dr. Erling Dorf has spent a part of the year in a study of the occurrence of plant remains in the sediments of the Parícutin volcano in Mexico.

## BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, H. W. MILNER, AND G. J. HARDIN

### CHLORELLIN AND SIMILAR ANTIBIOTIC SUBSTANCES

In the report of last year were described the first attempts to isolate material showing antibiotic activity from cultures of the green alga *Chlorella pyrenoidosa*. These efforts were based upon the fact that the first indications of antibiotic effects from this source were obtained from extracts of the culture solutions. In these first experiments the culture solutions, after being freed of the algal cells, were extracted either with organic solvents, or, more practicably, by means of columnar adsorption on a special preparation of magnesium silicate. The material obtained showed antibacterial properties against both Gram-positive and Gram-negative organisms; it

was obtained in yields of 0.15 to 0.3 gram per 15 liters culture solution, and for convenience of reference was designated by the name chlorellin.

For the most part the cultures were grown in a greenhouse, and the best yields of chlorellin were obtained during the summer months, when the plants were exposed to long periods of high light intensity and when the temperature of the cultures rarely reached 40° C. An extensive series of experiments was carried out with a view to excelling the yields obtained under these conditions. Various environmental factors were altered, singly and in groups, including temperature, length and intensity of illumination by the use of fluorescent and incandescent

lamps, concentration of carbon dioxide, etc. The objective of obtaining higher yields of chlorellin from the culture solutions was never attained; in fact, under many conditions the yields were exceedingly small, and the conclusion seems warranted that the highest chlorellin production in the nutrient solution occurs under conditions of high radiant-energy input. These conditions have previously been found to favor the production in *Chlorella* cells of the more highly reduced carbon compounds, such as fats and hydrocarbons. It was soon realized that the small yields of antibiotic material which are obtainable from culture solutions would necessitate the use of huge amounts of culture solutions in order to obtain sufficient material for chemical study, and that if such cultures were to be grown under artificial illumination this would entail the expenditure of a very considerable amount of electrical energy.

Because of the small yields of chlorellin obtainable from the cell-free culture solutions and because of the rather cumbersome technique involved in handling large volumes of solutions, efforts were made to obtain material showing antibiotic activity directly from the *Chlorella* cells after their separation from the culture solutions. On the average, a 15-liter unit of *Chlorella* culture produced 110 grams of fresh cells, 30 grams when dried, in about 30 days; considerably larger yields of cells were obtained with longer periods of growth of the cultures. From the immediate extraction of fresh *Chlorella* cells no material showing antibiotic properties was obtained, or only exceedingly small amounts. The extraction of cells which had been dried *in vacuo* at 60° C. yielded a little material with antibiotic activity, and cells which had been dried in this manner and had then been finely ground gave higher yields of active material. Moreover, when cells

which had been dried and ground were exposed to the air for several days, or were heated in air to 110° C. before extraction, the yield of active material was considerably increased. These observations led to the experimental demonstration that the antibiotic substance extracted from dried cells arose from oxidative reactions occurring in the dried plant material and that this reaction, or series of reactions, was stimulated by light. In order, therefore, to obtain larger yields of the antibiotic material from the *Chlorella* cells it was necessary to subject the dried cells to a preliminary process of fine grinding and exposure to air. The antibiotic material obtained in this manner was in the form of a thick yellow or brown oil. When this was subjected to saponification, an almost colorless crystalline product was obtained, melting at about 40° C. and of slightly higher antibiotic activity than the original oil.

The process of extraction of the *Chlorella* cells was further simplified by the adoption of a saponification-extraction procedure in which the fresh, or dried, cells are treated directly, at ordinary temperatures, with 80 per cent methanol containing 2 per cent of potassium hydroxide. In this process the cells undergo disintegration, resulting in the thorough extraction of the plant material. The material insoluble in the alkaline methanol is separated by centrifugation; the solution is acidified and thoroughly extracted with petroleum ether. The material soluble in petroleum ether, when freed from this solvent, is a brown, partly crystalline mass. It shows no antibiotic activity. When exposed to oxygen or air it becomes an almost colorless, crystalline mass, the reaction being definitely accelerated by light. This material now shows decided antibiotic activity. The activity is not significantly reduced by heating in an autoclave to 120° C., and only a very small portion thereof is volatile

with steam. The saponification-extraction method has greatly increased the amount of chlorellin available for experimental purposes. Several hundred grams have been prepared by this method, the production being limited chiefly by the amount of *Chlorella* cells available for extraction.

There is little doubt that the antibiotic activity of substances derived from *Chlorella* cells is the result of an oxidation reaction. In the one case this oxidation occurs in the killed and dried plant material; in the other case it occurs after lipoidal material has been removed from the cells and has been freed of the solvent used for its extraction. It is impossible to say to what extent an oxidative reaction of this nature occurs in the living *Chlorella* cells. The indications are, however, that there is very little antibiotic material in the living or freshly killed cells and also that comparatively little of such material accumulates in the nutrient solution in which the cells are cultured. As a consequence, only relatively small amounts of the antibiotic are obtainable from the cell-free culture solutions by means of the columnar adsorption method. If, however, cultures are killed by pasteurization (53-56° C. for 4 hours) and are then exposed to light and air, the amount of antibiotic recoverable by adsorption is greater than that recoverable from similar pasteurized cultures maintained free of air, that is, in an atmosphere of carbon dioxide. As yet, it has not been established with the desired chemical certainty that the antibiotic material derived from the culture solutions is identical with that obtained by extraction of the cells and subsequent oxidation. In all probability we are dealing with mixtures of very similar compounds, the separation of which is difficult, as has been found to be the case with several other antibiotic substances.

From the information gained through

the study of the material extracted from the cells it has become evident that the antibiotic material is of lipoidal nature; it is apparently accompanied by a fat-soluble pigment.

The material first obtained by means of the saponification-extraction method is easily soluble in petroleum ether. After exposure to oxygen and light it is less soluble in this solvent and its solubility in methanol and in water is increased. Partition between petroleum ether and 80 per cent methanol makes possible the extraction of much of the active material in methanol, but because of complex mutual solubility relations, it has not been possible to attain a complete separation of the active material from inactive components by this means. Nor have other methods been found to attain this goal.

The material obtained by the saponification-extraction method is in all probability a mixture of unsaturated fatty acids. Combustion analyses substantiate this opinion and also show that exposure to oxygen and light results in material of higher oxygen content than the original extract. For example, an original, inactive extract, on analysis, showed the following composition: 77.35 per cent carbon, 11.66 per cent hydrogen, and 10.99 per cent oxygen; after exposure to oxygen and light the analysis was as follows: 73.29 per cent carbon, 10.86 per cent hydrogen, and 15.85 per cent oxygen. It should be emphasized that these results represent the analysis of a mixture and that probably only a portion thereof has antibiotic activity.

Further indication that we are dealing with a mixture of fatty acids is obtained from the distillation of the material before exposure to air and light. This material is readily distilled at pressures of 5 to 8 microns and 65° to 220° C. Only a very small fraction fails to distill, and there is no evidence of decomposition. All dis-

tilled fractions approximate the composition of an unsaturated fatty acid on the basis of combustion analysis. The material which has been exposed to air and light, and which shows antibiotic activity, contains a larger proportion of oxygen in the distilled fractions. The amount of material which fails to distill is larger, and this also contains a larger proportion of oxygen than the corresponding residue of the unexposed material. The distillation of the exposed material is accompanied by some decomposition, and there is indication of the formation of easily volatile substances through the splitting of larger molecules.

Additional evidence of the unsaturated nature of the material extracted from *Chlorella* cells is gained from its behavior on catalytic hydrogenation and from its iodine number. The product obtained by saponification-extraction, before it has been exposed to air and light, readily undergoes hydrogenation. Thereby a considerable portion of the product is converted into stearic acid. The hydrogenated material shows no antibiotic properties; nor is any antibiotic substance formed when the hydrogenated material is exposed to air and light. The product obtained by saponification-extraction has an iodine number of 172. After hydrogenation, only an insignificant amount of iodine is absorbed. The neutralization equivalent of the hydrogenated material is 362.

By contrast, the material obtained by saponification-extraction which has subsequently been exposed to air and light, and which has thereby taken on antibiotic properties, absorbs about 30 per cent less hydrogen. This hydrogenated product contains only small amounts of stearic acid and, in contrast with its parent substance, shows little antibiotic activity. The product exposed to air and light has an iodine number of 107. After hydrogenation it has an iodine number of about 10. The neu-

tralization equivalent of the material exposed to air and light is 384 and, after hydrogenation, 394. A positive correlation was found between antibiotic activity and the Kreis rancidity reaction of these products, though it has not yet been established to what particular compound or group of compounds this reaction may be due. Nor is it certain that this parallelism will be maintained in the more highly purified products showing antibiotic activity.

In view of the fact that the cumulative evidence regarding the chemical nature of chlorellin showed definitely that unsaturated fatty acids were involved, a number of such acids of known constitution were treated in the same manner as were the *Chlorella* extracts and the resulting products were tested for antibiotic properties. For this purpose the following unsaturated fatty acids were examined: linoleic, elaidic,  $\beta$ -eleostearic, and  $\beta$ -licanic acids. None of these showed any antibiotic activity before exposure to oxygen and light. After they had been exposed to this treatment, in the solid or oily state, they all gave definite antibiotic reactions when tested in the same manner and in the same concentrations as used for the chlorellin tests. On the other hand, stearic acid, a saturated fatty acid, showed no antibiotic activity either before or after exposure to oxygen and light. In this connection it is not without interest that carotene, an unsaturated hydrocarbon, also develops antibiotic activity on exposure to oxygen and light, although the reaction proceeds more slowly than is the case with unsaturated fatty acids.

It is evident, therefore, that various unsaturated fatty acids, which are common constituents of naturally occurring vegetable fats, behave in a manner very similar to that observed in extracts of *Chlorella* cells. The results obtained thus far indicate that antibiotic material of the nature

of chlorellin can be produced from a variety of unsaturated compounds and that the antibiotic activity is probably not due to a single oxidation product. It was realized, of course, that the oxidation of unsaturated fatty acids results in the formation of peroxides, including hydrogen peroxide, and that the latter has bactericidal properties. Preparations of chlorellin and fatty acids exposed to oxygen and light were treated with thiourea or with thiourea and potassium iodide in order to destroy labile peroxides which might be present. By this treatment the antibacterial activities were not reduced significantly, a fact which indicates that not much of the activity can be due to labile peroxides.

These investigations were largely based upon the observation that cultures of *Chlorella* are autoantibiotic, that is, such cultures produce substances that are inhibitory to their own development. It was in the belief that this autoantibiosis may prove to be heterantagonistic, and because purely autotrophic microorganisms had not been studied for the production of antibiotics, that these investigations were pursued. Since the antibiotic properties of the preparations obtained from *Chlorella* appear to be due to unsaturated fatty acids or at least to be associated with these compounds, it seemed important to determine whether similar preparations could be obtained from the lipid extracts of other plants. Such has, in fact, now been found to be the case. By the use of the same methods of extraction as employed with *Chlorella*, extracts showing very similar properties and having approximately the same antibiotic activities have been obtained from a variety of plants. The same phenomenon was observed, namely, that the first extracts of the plants showed no antibiotic activity, but that this was produced on exposure of the extracts to oxygen and light. The plant tissues examined

include chlorophyll-bearing as well as pigment-free tissue. The plants from which such preparations have been made were: the green leaves of alfalfa, ailanthus, spinach, sunflower, flax, also cabbage, turnips, carrots, the fruit of avocado, and baker's yeast.

The antibiotic activity of the various preparations of chlorellin was measured by the Oxford cup test technique, the organism for routine tests being *Staphylococcus aureus* (Food and Drug Administration No. 209). Similar tests using other bacteria showed that chlorellin is active against *E. coli* and several strains of *Shigella dysenteriae*. Streptococci were but little affected. Dr. Sidney Raffel, who kindly supplied us with most of the bacterial strains used for these assays, is also testing the activity of chlorellin against various other pathogenic bacteria both *in vitro* and *in vivo*, but these investigations are not far enough advanced to warrant report at this time. The use of infected animals in assaying antibiotics is a specialized and exacting technique demanding talents somewhat different from those available in our own laboratory; consequently we consider ourselves fortunate in having the advice and wholehearted cooperation of Dr. Raffel and Dr. Winsor Cutting on this phase of the work.

It may prove to be of considerable interest that the antibiotic here described, which was first obtained from cultures of *Chlorella pyrenoidosa*, and which for convenience was designated as chlorellin, has proved to be very similar to pyocyanase, the first antibiotic, recognized and isolated over a half-century ago from *Pseudomonas aeruginosa*. Although pyocyanase has for some time been the subject of extensive investigation, its chemical composition has not been definitely established. There are, however, a number of points of similarity between chlorellin and pyocyan-

ase which may make a comparative study of the two antibiotics a profitable undertaking. They are both heat-resistant; their solubility in organic solvents is very similar; in both, unsaturated fatty acids are definitely associated with the antagonistic action toward a variety of microorganisms. It is conceivable that the tremendously complex interrelations involved in microbial antagonism could in a measure at least be clarified on the basis of the chemistry of the substances responsible for these antagonistic reactions. Biological antagonism is a natural phenomenon, doubtless occurring throughout the entire biocoenose of which man is a part. The urge on the part of man to obtain therapeutic agents capable of suppressing bacterial pathogens is natural and of the greatest importance. Yet it is also important to know to what extent man is unwittingly protected from bacterial infection because of antibiotic substances which are ingested with his food or which the body manufactures or which are the result of old sanitary customs. It would seem to be quite as important to know something about the natural protective agents, that is, man's own

antibiotics, as to discover means of combating bacterial organisms after they have invaded the body. The former would be at least an important part of scientific hygiene.

From this point of view the unsaturated fatty acids, which are common constituents of many plants, are deserving of more careful study. The chemistry of this group of compounds has been well developed, so that a vast body of scientific knowledge is available. It is possible that the antibacterial action of this class of compounds may be of a highly specific character, as appears to be the case with chaulmoogric acid. Although as compared with penicillin, for example, the antibiotic activity arising from the unsaturated fatty acids has thus far been found to be of relatively low potency, the mixture of fatty acids obtained from *Chlorella* cells has not been resolved, and only a modest beginning has been made in the study of individual components. It is possible that the antibiotic properties associated with unsaturated fatty acids may make them useful prophylactic agents in the form of soaps and cleansing agents.

## EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, AND WILLIAM M. HIESEY

The range-grass program, initiated in 1943 in cooperation with the Soil Conservation Service of the U. S. Department of Agriculture, has advanced to a point where its practical and scientific potentialities can be evaluated with reasonable clarity. The primary objective has been to produce through hybridization new grasses of value under conditions of the open range, and to explore new approaches to the breeding of forage grasses. This is being accomplished by obtaining nonsegregating hybrids with increased climatic tolerance

from crossings between remotely related species from contrasting climates.

*Poa*, or bluegrass, was chosen because its species are important for forage in almost all parts of the world, and because many of them produce their seed largely asexually. Only a small percentage of the seed is formed as a result of fertilization, so the great bulk of it produces offspring just like the mother plant. Hybrids between such species likewise produce their seed largely asexually, and so are non-segregating and fertile. The small per-

centage of offspring arising from fertilization includes the hybrids, which for this reason are rare. This disadvantage is counterbalanced by the fact that the hybrids do not segregate once they are obtained. The superior hybrids can therefore be selected in the variable first generation, as each individual of this generation is a potential starting point for a new, distinct, and practically constant race.

*Poa* is also well adapted for large-scale attempts at combining the genomes of species fitting very different environments, for its forms are found in most of the environmental niches within the temperate and arctic zones. Scientifically, it is attractive for a study on speciation in a group that is evolutionarily so mature that reproduction is largely asexual, and also for an exploration of certain important aspects of ecological genetics.

Of no less importance is the fact that the practical application of scientific principles is being tested through this program. Plant breeding is applied evolution. Fundamental to the intelligent planning of a breeding program is an understanding of the evolutionary relationships within the groups to be bred, but these relationships are largely elucidated through the crossings. The scientific and practical objectives are therefore interwoven.

Spontaneous crossing has undoubtedly taken place in *Poa* through the ages, and some of the artificial hybrids resemble certain of the taxonomically critical species in western North America, suggesting that the latter may have arisen through hybridization. This does not mean, however, that the possibilities have been exhausted, for spontaneous crossing is limited to such species and races as happen to grow and flower together, but the breeder can cross races that would never occur together in the wild.

About 180 hybrid individuals were ob-

tained among 38,000 seedlings grown from 26 crossings made in 1944. These represented 21 strains from 9 species and 3 sections of *Poa*. This number of hybrids is in addition to the 13 obtained among 4500 seedlings from the 1943 crossings. Also, 3 spontaneous intersectional hybrids were discovered.

Most of the hybrids are between species belonging to very different sections of the genus. They differ greatly in vigor, some individuals exceeding either parent. The yield of good seed also varies, but in a surprising number of cases, as many as 15,000 to 50,000 seeds per plant were obtained. In the more promising hybrids the percentage of good seeds varies between 35 and 90, a range of fertility which is similar to that observed in the parental form. Such wide hybrids could not have yielded so much had their seed been produced by fertilization; therefore, the results strongly indicate that they, like their parents, set most of their seed asexually, and that they will be constant.

It is also now obvious that in these crossings between extremely remotely related species, the vigor of the hybrids and the frequency of their occurrence depend upon how well the genomes of the parents fit together. The most vigorous hybrids do not always arise from the most vigorous parents. Also, two plants that yield a low percentage of hybrids in other combinations may produce a high percentage when crossed together. The hybrid frequency varies between 0.06 and 4.95 per cent, with a mean of 0.46 per cent.

#### BREEDING STOCK

The breeding procedure is relatively simple in a group having the evolutionary maturity of *Poa*, in which the entire genome, rather than the individual gene, has become the evolutionary building

block, and the hybrids do not segregate. It consists in fitting together the available genomes into successful new combinations that combine the desirable characteristics of widely distinct species. For this purpose it is important to have a diversified stock from which to select the genomes.

About 4500 plants representing 160 new strains of 23 species of *Poa* have been started in the gardens of the Carnegie Institution at Stanford University this year. Some of these potential breeding stocks were obtained through our collections in California; others were received through the courtesy of the Division of Forage Crops and Diseases of the Bureau of Plant Industry, representing strains from widely different parts of the United States and of the world; still other seeds, representing the Rocky Mountain region, were received from Dr. B. F. Harrison, of Brigham Young University, Provo, Utah, and Dr. C. L. Porter, of the University of Wyoming. The evolutionary relationships and characteristic reactions of these races will be studied. Two growing seasons are required for most of the forms to come to full maturity.

The species of *Poa* that offer the greatest promise for breeding belong to two contrasting sections of the genus. One section consists of the bunch-grass Poas of western North America, including the members of at least the sections *Nevadenses* and *Scabrella* of Hitchcock's Manual. Here are found some of the largest Poas, but they are specialized in their habitat requirements and are very modifiable, hence are unsuitable for introduction in a wide range of climates. They are usually winter-active and summer-dormant under the climatic conditions at Stanford.

The members of the other group are the rhizome-developing species of the *Pratenses*. They are generally winter-dormant

and summer-active. This section is worldwide in distribution, with many local species and at least one that is cosmopolitan, *Poa pratensis* L., the Kentucky bluegrass, one of the most tolerant and least modifiable species known. A form of it from a subarctic bog at 68° north latitude has been growing successfully in the heavy dry soil at Stanford, 30° farther south. A strain from the Athabasca region of western Canada grows vigorously at Stanford without irrigation or summer precipitation. The wide range of tolerance and the slight environmental modifiability of *Poa pratensis* and its relatives make them suitable for agriculture, and it is hoped that some of this adaptability can be transmitted to their hybrids with the bunch grasses.

The *Poa* investigations will be limited largely to these two sections, whose species and races offer a striking array of differences in form and in seasonal periodicity related to the environment.

#### Poa HYBRIDS

The technique employed and the objectives guiding the crossing experiments were described in Year Book No. 43 (pp. 73, 75). Mass pollination in cages is used, and the hybrids are distinguished from the nonhybrid seedlings of maternal type in the young seedling stage. The extreme rarity of the hybrids makes it necessary to grow large numbers of seedlings, which are pricked out into flats and spaced accurately to facilitate methodical examination. The hybrids can be detected in the 8- to 12-leaf stage, when 2 to 3 months old, and most of the numerous nonhybrid plants can then be eliminated.

Several crossings were made this year between species that ordinarily flower at different seasons. Such was the case in the crossing of the California bluegrass, *Poa*

*scabrella* (Thurb.) Benth., which flowers in February and March, and the Canada bluegrass, *Poa compressa* L., which is activated by day length and flowers at Stanford in June. It was found that *scabrella* seedlings will flower about three months after sowing, and so by regulating the planting time it was possible to use *scabrella* for crossing with *compressa* and other late-flowering species. Likewise, the earliest strains of *pratensis* were held dormant in cold storage at the Bellingham, Washington, station of the Soil Conservation Service. Plants thus delayed could then be used for crossing with *P. nevadensis* Vasey and the latest-flowering strains of *P. ampla* Merr. Flowering in *ampla* is delayed when the plants are kept in the greenhouse, probably because of reduced light intensity. Such plants were used for crossing with *compressa*, which otherwise blooms later than *ampla* at Stanford.

Reciprocal crossings were made systematically for the first two years. No hybrids, however, were obtained on *pratensis* as the maternal parent, and very few on any member of the *Pratenses*. It was at first thought that this finding might be due to the dominance of *pratensis* characters in juvenile stages, making difficult the discovery of the hybrids among the *pratensis* seedlings. Older hybrids, however, are readily recognized as distinct from *pratensis*, yet none have been discovered among 8000 seedlings raised to maturity from seed harvested on *pratensis* after heavy pollination by *ampla* and *scabrella*. Apparently, then, hybrids occur only on the bunch grasses when pollinated by *pratensis*, and not in the reciprocal combination. This is possibly another indication of the remote genetic relationship between the two groups. Because of this finding, and in order to obtain the greatest yield of hybrids, the pollen now is carried only from the rhizome grass to the bunch grass.

The results of the crossings made in 1943 and 1944 show that in hybridizations between such remotely related species it is impossible to predict accurately which combinations will produce the best hybrids. Further exploration of the hybrid possibilities in the genus has therefore been necessary. Crossings have now been made between key climatic races of *Poa ampla* Merr., *P. scabrella* (Thurb.) Benth., *P. nevadensis* Vasey, and an alpine race of *P. secunda* Presl of the bunch grasses, on the one hand, and *P. pratensis* L., *P. Kelloggii* Vasey, *P. arida* Vasey, and *P. compressa* L. of the rhizome grasses, on the other. These are in addition to more scattered crossings utilizing *P. Canbyi* (Scribn.) Piper, *P. nervosa* (Hook.) Vasey, *P. arachnifera* Torr., and *P. longifolia* Trin. The 26 combinations attempted this spring raise the total number of different crossings to 59. Some 19 different hybrid combinations have already been obtained, and the new crossings can be expected to double this number.

The hybrids already obtained probably give a fairly reliable picture of the breeding possibilities in these two agronomically important sections of *Poa*. The characteristics of those that are already mature make it almost certain that desirable and constant new range types can be produced from such intersectional crosses.

A list of the hybrids growing in 1945, which are the results of the 1943 and 1944 crossings, is given in the table on page 75. The percentage of hybrids obtained is indicated for each of the 19 combinations; it is almost uniformly a low figure.

Most intersectional  $F_1$  hybrids of *Poa* are so variable that it is difficult to characterize any one combination. Three examples among the more outstanding are discussed below and include (1) *Poa ampla*  $\times$  *pratensis*, (2) *P. ampla*  $\times$  *compressa*, and (3) *P. scabrella*  $\times$  *pratensis*.

## POA HYBRIDS, 1944-1945

Crossing	No. of hybrids	Per cent hybrids
<b>AMPLA X PRATENSIS, 84 hybrids:</b>		
<i>ampla</i> , E. Washington, $\times$ <i>pratensis alpigena</i> , Lapland	7	2.30
<i>ampla</i> , E. Washington, $\times$ <i>pratensis</i> , Mather	57	4.95
<i>ampla</i> , E. Washington, $\times$ <i>pratensis</i> , Athabasca region	20	0.10
<b>AMPLA X ARIDA:</b>		
<i>ampla</i> , E. Washington, $\times$ <i>arida</i> , Nebraska, and reciprocal	3	0.27
<b>AMPLA X COMPRESSA:</b>		
<i>ampla</i> , E. Washington, $\times$ <i>compressa</i> , Asia Minor, and reciprocal	5	0.20
<b>CANBYI X PRATENSIS:</b>		
<i>Canbyi</i> , Blue Mts., $\times$ <i>pratensis</i> , Athabasca region	1	2.04
<i>Canbyi</i> , Blue Mts., $\times$ <i>pratensis</i> , Great Basin race	0 (2500 seedlings)	
<b>NEVOSA HYBRIDIZATIONS:</b>		
<i>nervosa</i> ♀ $\times$ <i>Canbyi</i> (2 crossings)	0 (1255 seedlings)	
<i>nervosa</i> ♀ $\times$ <i>scabrella</i> (3 crossings)	0 (1155 seedlings)	
<b>NEVADENSIS X COMPRESSA:</b>		
<i>nevadensis</i> , E. Oregon, $\times$ <i>compressa</i> , Asia Minor	4	1.18
<b>NEVADENSIS X LONGIFOLIA:</b>		
<i>nevadensis</i> , W. Idaho, $\times$ <i>longifolia</i> , Armenia	1	0.21
<b>SCABRELLA X AMPLA</b> , possibly 15 hybrids:		
<i>scabrella</i> , S. California, $\times$ <i>ampla</i> , E. Washington	3?	0.27
<i>scabrella</i> , Cent. California, $\times$ <i>ampla</i> , E. Washington	6 + 6?	0.98
<b>SCABRELLA X PRATENSIS</b> , 65 hybrids:		
<i>scabrella</i> , S. California, $\times$ <i>pratensis</i> , Athabasca	11	0.35
<i>scabrella</i> , S. California, $\times$ <i>pratensis alpigena</i> , Lapland	2	0.23
<i>scabrella</i> , S. California, $\times$ <i>pratensis</i> , Mather	19	1.34
<i>scabrella</i> , S. California, $\times$ <i>pratensis</i> , Great Basin	8	0.61
<i>scabrella</i> , Cent. California, $\times$ <i>pratensis</i> , Athabasca	12	0.17
<i>scabrella</i> , Cent. California, $\times$ <i>pratensis</i> , Great Basin	2	0.06
<i>scabrella</i> , Mather, $\times$ <i>pratensis alpigena</i> , Lapland	1	0.23
<b>COASTAL SCABRELLA X HIGH-ALTITUDE SECUNDA</b> , possibly 29 hybrids:		
<i>scabrella</i> ♀, Cent. California, $\times$ <i>secunda</i> , Timberline	5?	2.11
<i>scabrella</i> , N. California, $\times$ <i>secunda</i> , Timberline, and reciprocal	24?	1.57

1. *Poa ampla*  $\times$  *pratensis*. This hybrid combines the best of the bunch-grass Poas from the dry Palouse prairie region of eastern Washington and Oregon with the outstanding rhizome-producing species that usually grows in meadows. These species differ considerably in their time of flowering at Stanford, but cross fairly readily, for 84  $F_1$  individuals have been obtained in 3 combinations. In addition, 3 spontaneous hybrids were found in 3

cultures grown from seed received from the Soil Conservation Service.

The *ampla-pratensis* hybrids generally combine the winter activity of *ampla* with the rhizomes, summer leaves, and increased rust resistance of *pratensis*. When mature, they are different from either parent and readily recognized, but like *pratensis* they do not flower before the second year.

The only *ampla-pratensis* combination

sown in 1944 was a cross between a very tall race of *ampla* from the eastern Washington prairie and the *alpigena* form of *pratensis* from a bog 2° north of the Arctic Circle in Swedish Lapland. One would expect these hybrids to be best adapted to climates of northern latitudes, like that of temperate Canada or southern Scandinavia. Sister hybrids are so unlike that they appear to belong to distinct species. Each one is potentially the starting point of a new constant and distinct form. Two or three of them are of promise, and are doing well even at the relatively southern latitude of Stanford. One has inherited the long, glaucous leaves, winter activity, and very large inflorescences of *ampla*, together with the soft leaf texture, partial summer activity, short rhizomes, and short culms of *alpigena*. It has also inherited some of the rust resistance of the latter. It is only about 33 per cent fertile, like its *ampla* parent, yet it was able to produce some 50,000 good seeds.

Another promising *ampla-pratensis* plant is a spontaneous hybrid of unknown *pratensis* parentage discovered among seedlings of a desirable race of *ampla* from Condon, northern Oregon. The seed was harvested on Condon *ampla* at the Pullman nursery of the Soil Conservation Service. The lone hybrid stood out distinctly from the *ampla* plants in the row. Although it is winter-active like *ampla*, it flowers about three weeks earlier, and then remains green longer. It is more floriferous, and its leaves, although somewhat shorter, are more numerous and darker green. Also, it is more rust-resistant. In loose soil it develops short rhizomes, but it would be classified normally as a bunch grass, and would pass for an improved form of *ampla*. It was more vigorous and taller than its *ampla* parent and than any *pratensis* strain grown at Stanford. Its chromosome number,  $2n = 92$ , suggests

that it has two genomes of *ampla* and one of *pratensis*. This plant, which produced some 18,000 good seeds, is 40 per cent fertile, ranking with some *ampla* forms from the wild.

Still better *ampla-pratensis* hybrids are anticipated. A cross between two highly apomictic strains, one the most vigorous form of *ampla* from eastern Washington, the other a disease-resistant form of *pratensis* from a meadow at our Mather station, has produced 57 hybrids out of approximately 1200 seedlings. These are more uniformly vigorous than any of the other hybrids, but they will not flower before next year.

2. *Poa ampla*  $\times$  *compressa*. The Canada bluegrass, *Poa compressa*, is a Eurasian rhizomatous species from drier habitats than *pratensis* that has been able to establish itself widely. Hybrids between it and *ampla* combine the genomes of two fairly drought-resistant species. Five hybrid individuals were obtained between the largest form of *ampla* from eastern Washington and a form of *compressa* from the Mediterranean slopes of Asia Minor at 4000 feet altitude. Two of these resemble *compressa*, a third is a dwarf, and a fourth is sterile. These four have between 50 and 60 chromosomes, and are probably composed of one genome from each parent.

The fifth hybrid, however, is an outstanding form. It has about 86 chromosomes, and probably arose from a diploid *ampla* ovule with 63 chromosomes and a haploid *compressa* pollen with approximately 23 chromosomes. This hybrid is winter-active like *ampla*, and during the summer it is still green after both parents have become semidormant. It has inherited the glaucous leaves of *ampla*, together with the rust resistance and short rhizomes of *compressa*. This plant, which is much more vigorous than *compressa* and compares favorably with forms of *ampla*, may

be of use in extending the summer grazing season in some dry sectors of the country. It is as fertile as the best, namely 85 per cent, and has produced about 35,000 good seeds in one season.

These five *ampla-compressa* hybrids, all from the same two parents, illustrate the variability to be found when species of two different taxonomic sections are crossed. In many respects, the  $F_1$  of these partially apomictic species resembles the  $F_2$  of sexual species, and it is important to have sufficiently large  $F_1$  populations to afford material for selection of superior types.

3. *Poa scabrella*  $\times$  *pratensis*. The parental species, California bluegrass, *P. scabrella*, and Kentucky bluegrass, *P. pratensis*, are complementary in their characters, and the hybrid combines the best of the two. Thus, although the *scabrella* parent is a rather weak, unimpressive species, the hybrid has unexpected vigor and gives promise of becoming one of the most successful combinations.

*Poa scabrella* is highly specialized to fit the climates where it is native. It is largely limited to the California Coast Ranges and the slopes surrounding the Great Valley and those of the Sierra Nevada to mid-altitudes. All its forms are distinctly winter-active and completely summer-dormant. After May or June there is no sign of life until new leaves develop in the cool fall even before the first rains come. Forms from the outer Coast Range flower in February and March. At least three ecotypes are apparent. The one from the outer Coast Range is the most vigorous and the only one of promise for breeding. It is the only form that is able to develop a second crop of leaves after flowering if the weather stays cool. Under conditions at Stanford the forms from the Transition Zone in the Sierra Nevada flower 4 to 6 weeks later than those from the outer Coast Range, yet they go dormant earlier.

This relatively ephemeral bunch grass is resistant to mildew and fairly resistant to rust; also, it is very rapid in development. Seedlings will flower in 90 days. In addition to these desirable characteristics, it was realized that *scabrella* is well adapted to a southern mild climate and can furnish a genome to counterbalance those of species from northern latitudes or high altitudes.

A total of 65 *scabrella-pratensis* hybrids were obtained this year in 7 crossings, using as parents two Coast Range and one Sierran race of *scabrella*, paired with races of *pratensis* from Lapland, Canada, the Sierra Nevada, and the Great Basin plateau. The hybrids were recognized by several characters 2 to 3 months after sowing.

The *scabrella-pratensis* hybrids have inherited the summer activity and the long leaves of *pratensis*, and, judging from other hybrids between winter-active and winter-dormant species, they may also be expected to be winter-active. Such a hybrid might become dormant during cold winters or dry summers, or remain perpetually active under favorable conditions, thus providing wide adaptability to different circumstances. This hybrid resembles the *scabrella* parent in its quick development, for it flowers the first season, only 2 or 3 weeks later than *scabrella*, whereas *pratensis* ordinarily does not flower until the second year. It is much less rhizomatous than the *ampla-pratensis* hybrids, but produces more tillers than the *scabrella* parent.

Unexpectedly, the most vigorous hybrids occurred in a cross between a *scabrella* form from coastal Ventura County, southern California, and a very mildew-susceptible form of *pratensis* from the desert plateau near Mono Lake at 6500 feet. The latter plant comes from an arid, alkaline region with a very severe winter and a hot summer, whereas the *scabrella* parent is from the coastal fog belt with a mild

winter and summer climate. A hybrid combining the genomes of such forms should have a considerable range of tolerance for different climates. All 8 of the hybrids obtained were mildew-resistant. The fertility was variable, but the best plant in other characters was 90 per cent fertile, and its three inflorescences produced some 3500 good seeds. From preliminary tests, this hybrid appears to be more productive and fertile than either parent. Its chromosome number is  $2n = 70$ , as compared with 84 and 68 in the parents.

Not all hybrids are so promising as those in the three groups mentioned. Some are definitely weak, as for example *Poa scabrella*  $\times$  *ampla*. This hybrid between members of the bunch-grass section unites the genomes of a species from the southern coast and one from the dry northern interior. The few hybrids obtained are distinctly weak, but remain green longer than *scabrella*. None have shown a tendency to flower the first year.

Another weak hybrid is *Poa nevadensis*  $\times$  *longifolia*. The Nevada bluegrass, which is a close relative of *ampla*, is from montane meadows east of the Sierra Nevada and the Cascades. The other parent, *Poa longifolia*, is a coarse bunch grass from the Caucasus region, but it is unrelated to the American bunch grasses. The single hybrid obtained was only a small rosette of leaves when 8 months old, much smaller than either parental type of the same age. Obviously, the genomes of these two species do not fit together.

These divergent results indicate that a number of exploratory crossings are necessary to determine which combinations will produce the most successful hybrids. Then further crossings can be made for the purpose of combining the proper ecotypes of these species to fit the desired environmental niches. This type of breeding is relatively simple as compared with breed-

ing by gene exchange between genomes, for in the latter case many generations are required before constancy can be attained when many exchangeable genes are involved.

Summarizing the results of the crossings, it is demonstrated that intersectional hybrids between many species of *Poa* can be obtained; that the first hybrid generation is highly variable; and that the combinations of some species are generally vigorous, and those of others are weak. Furthermore, it is possible to combine favorable characteristics of the two parents in many intersectional hybrids, and some hybrids are as fertile as their parents or even more so. High fertility in intersectional hybrids in this case should indicate that the offspring is produced without fertilization and will be constant.

#### TRANSPLANT EXPERIMENTS

In Year Book No. 43 (p. 77) it was mentioned that the *Poa* hybrids and the parental strains would be tested at the three transplant stations in order to determine their ecological characteristics and their fitness to different climates. Clones of parent plants and of the first hybrids were transplanted during 1944 and 1945, and recent hybrids and their parents will follow as soon as available. Other forms of critical interest will be transplanted as their importance becomes apparent. *Poa pratensis*, for example, has now been collected at from 3000 to 10,000 feet altitude in the Sierra Nevada, and a closely related form, *P. Kelloggii*, has been obtained from coastal bluffs in Oregon. These, with forms from the desert ranges, constitute a series from very different climates worthy of being tested and classified ecologically at the transplant stations.

In addition, a nonhybrid series of variable offspring from one individual of the

giant *ampla* from Albion, Washington, was transplanted. These differ in their chromosome numbers, belonging to a slightly obscured 7 series, with  $2n = 56$ , 63, 66, 70, 90-93, 98-100, and 126 chromosomes. There are several plants in each of the 90-93 and 98-100 chromosome groups. These numbers approximate 8-, 9-, 10-, 13-, 14-, and 18-ploid. At Stanford, these plants vary considerably in vigor, fertility, and susceptibility to disease, but all are characteristic of *ampla* and even of the Albion race irrespective of their chromosome number. *Poa ampla* normally has  $2n = 63$  chromosomes, 9 sets of 7, which is an unbalanced number. The parent of this series has 63 chromosomes, and no strain of *ampla* from the wild has been discovered with less. Therefore the plant with 56 chromosomes has lost one set of 7 chromosomes. Under the conditions at Stanford this loss appears to have been rather advantageous, for that plant is less susceptible to rust and has a seed fertility of 75 per cent as contrasted with 40 per cent in the parent. The fact that whole sets of chromosomes can be added to or subtracted from *ampla* without much effect on the morphology of the plant indicates that the same basic sets of chromosomes are duplicated a number of times, and that the species probably is highly autopolyploid.

The members of this autopolyploid series of *ampla* arose spontaneously, and the indications are that such variations may arise also in the natural populations. Since 63 chromosomes are uniformly found in *ampla* from the Palouse prairie, there is a possibility that a change in the chromosome number may be accompanied by a change in the fitness to the environment, which places the chromosomal aberrant at a disadvantage at its point of origin. The present transplant tests will indicate whether the differences in chromosome

number are accompanied by a change in ecological requirements.

When the hybrids at hand and those arising from this year's hybridizations have been established at the transplant stations, there will be available for study in three climatically very different gardens a unique series of *Poa*, consisting of many species and ecotypes and some 35 to 40 different hybrid combinations of these, as well as series of chromosomal aberrants like that mentioned. Study of this material should produce a new insight into the ecological characteristics of the basic forms, and the behavior of their genomes when combined in hybrids or changed by simple addition or subtraction of sets of chromosomes.

#### CYTOTOLOGY OF RANGE GRASSES

Miss Marguerite Hartung has continued the study on the chromosome numbers of *Poa* species and hybrids and on many species and strains of *Agropyron* and *Elymus*. A knowledge of the chromosome numbers of the forms is essential to an understanding of the evolutionary past and future of such groups.

*Poa*. The large number of chromosomes in most species of *Poa* makes their cytological investigation slow. This and the inherent difficulties in fixation and staining also make it difficult to determine positively whether the chromosomes are present in exact multiples of 7 or whether slight deviations exist. Some of the results were reported in Year Book No. 43 (pp. 74-75). The chromosome numbers of more than 115 races from 22 species of *Poa* are now determined. This has filled out gaps in our information, but has not essentially changed the picture presented in last year's report.

It is evident that in the Pacific states each species of the bunch-grass section is chromosomally relatively uniform, and all

are characterized by high numbers in multiples of 7. For example, *Poa scabrella* is usually duodecaploid, with  $2n = 82-86$  chromosomes; that is, its forms have approximately 12 sets of 7 chromosomes each. Occasional weaker individuals deviate, with  $2n = 63$  chromosomes, but they appear to be unimportant in wild populations. However, one vigorous population from near Clear Lake, northern California, has uniformly  $2n = 63$ . Its technical characters are those of *scabrella*, but it has coarser stems, more congested inflorescences, and a flowering period 2 months later than the other Coast Range strains. Therefore, its origin is probably different from that of the others. Likewise, a 70-chromosome race has been found in *Poa ampla* and in *P. nevadensis*, which normally have  $2n = 63$  chromosomes. Aberrations like these are to be expected in partially apomictic groups where vigorous deviators and new hybrids can immediately establish themselves as constant populations.

The western American bunch-grass Poas with high chromosome numbers must have had a long evolutionary history, but very few facts that can be expected to lead to an understanding of it have so far been found. The discovery of related primitive forms with low chromosome numbers would furnish keys to the solution of this problem. But if such forms still exist, they must be very rare. The only indication in this direction is the discovery of a hexaploid form of *scabrella* with about 42 chromosomes from the western edge of the Mohave Desert. This single plant is indistinguishable from the normal 84-chromosome form. Its existence merely tends to strengthen the impression that our present-day forms of these grasses have arisen from the earlier by a multiplication of their chromosomes, that is, through autoploidy.

*Poa pratensis* ranks as the chromosomally most variable species of the genus, and as one of the plants most tolerant to variation in chromosome number. Forms with  $2n = 49, 50, 56, 57, 67, 68, 70, 73, 74, 76$ , and 80 chromosomes have been found among races from the Pacific states, and  $2n = 81$  has been found in two races of the very closely related *P. Kelloggii* from coastal bluffs of Oregon. A fairly healthy form with  $2n = 36$ , half the normal number, was discovered among the aberrants of the *alpigena* form from Lapland. Some local populations of *pratensis* consist of several forms that differ in chromosome number. Asexual propagation makes it possible for such forms to be perpetuated once they arise. It appears that in the higher brackets of the series, the forms that deviate from the multiples of 7 are just as vigorous as those having chromosome numbers in multiples.

In spite of this extreme variation in chromosome number, *Poa pratensis* is not a critical species taxonomically, for its forms are easily recognizable and very different from all other Poas. There are no clues as to the origin of this remarkable species, from which chromosomes may be added or subtracted within the range of about  $2n = 18$  to 120 without its losing its identity. Its occurrence at very high altitudes in the mountains of western North America makes it certain that it is indigenous here, although some forms in agricultural areas have been introduced.

Many forms of *Poa* of hybrid origin are no doubt present in the vegetation of western North America. Some of these intermediate forms have been named as species; others have not yet been noticed. The crossing experiments have shown that morphologically very distinct forms with different chromosome numbers may arise within one cross. Species of parallel hybrid origin can therefore exist under differ-

ent names in distinct sections of the country. For example, the characters of *Poa fibrata* Swallen,  $2n = 64$ , in California, and *P. glaucifolia* Scribn. & Williams,  $2n = 50$ , in the intermountain states, are such that both could have arisen independently from spontaneous crossings between *Poa ampla* and *P. pratensis*. Likewise, two native strains from Washington are in culture which are very different from each other, but both of which appear to combine characters of *Poa ampla* and *P. Canbyi*. They have not received formal names, and although one has  $2n = 63$  and the other approximately  $2n = 88$  chromosomes, both could well be descendants from independent spontaneous crossings between these two species.

The synthesized *Poa* hybrids therefore will probably furnish some clues to the understanding of the intermediate forms that obscure the distinctions between the taxonomic sections. They point to the species of the future, whose forerunners already are elements of the vegetation, but they will not contribute much to the understanding of the makeup of the basic species from which they sprang.

*Agropyron* and *Elymus*. Another important group of forage grasses in western North America are the wheat grasses (*Agropyron*) and the wild rye (*Elymus*). Thirty individuals each of some 115 races of 19 species of these genera have been grown in the garden for two years in order to study and compare them and to determine their chromosome numbers.

These genera present a very different picture from *Poa*, for most of their species have relatively low chromosome numbers in strict multiples of 7, and they reproduce sexually. A few species are diploid, with 7 pairs of chromosomes, but most are tetraploid, with 14 pairs. Higher polyploids are uncommon; in our assemblage

only one species each has 21, 28, and 35 pairs of chromosomes.

More than one chromosome number has been found in some species of *Agropyron*. This situation usually indicates that such a species is heterogeneous, and that additional methodical investigation is required to clarify its composition and the origin of its forms. *Agropyron spicatum* (Pursh) Scribn. & Smith has 7 pairs of chromosomes over most of its territory, but there is a pocket of large tetraploids with 14 pairs in eastern Washington and western Idaho. The extremely variable *Agropyron Smithii* Rydb. is predominantly octoploid, with 28 pairs of chromosomes, as noted in races from Washington, Idaho, South Dakota, Kansas, and Texas, but a form from southeastern Oregon, near the periphery of the range of the species, has only 14 pairs.

Within a natural population the species of *Poa* are relatively uniform, but *Agropyron* and *Elymus* are highly variable, although some species vary more than others. In extreme cases individual differences within one population will involve even the technical characters that are used to separate *Agropyron* and *Elymus*, which probably are very artificial genera. Great morphological variation, and poorly defined species, are characteristic of genera having closely related species which will cross rather readily, and whose chromosomes are still largely homologous and able to pair in the hybrids. Amphibrids arising from hybrids between such species would be unstable and very difficult to breed to constancy.

In view of the complexity of the *Agropyron-Elymus* group, it has been decided to limit the grass studies to the two sections of *Poa*, particularly since progress in hybridizing members of this genus has been greater than anticipated.

## ACHILLEA STUDIES

The study of the transplant reactions of local populations of *Achillea* is now approaching its conclusion. The materials came from frequent intervals across central California in a line with the transplant stations from the coast to the Great Basin plateau east of the Sierra Nevada. They were discussed in Year Book No. 41 (pp. 127-132), and planted at the three stations in 1942. The unique range of climates covered by this transect and occupied by *Achillea*, the strategic sampling, and the reactional patterns as recorded from the three stations lead to an understanding of the basic characteristics of climatic races, or ecotypes. The analysis of the data and the preparation of illustrations for publication are well under way.

## FUTURE INVESTIGATIONS

The war temporarily interrupted a series of studies dealing with the laws that determine the hereditary and environmental relations of plants. These laws are basic to an understanding of organic evolution. Fortunately, the garden experiments have been completed. The very complete records preserved in the form of notes and plant materials can now be prepared for publication without the necessity of making new field collections. The *Poa* investigations have been conducted in such a way that they represent a further extension of this program.

These investigations on the organization of plant life, as viewed from coordinated cytogenetic, morphologic, geographic, and ecologic approaches, have extensively utilized the Madiinae, the climatic races of *Achillea*, and the selection experiment on *Potentilla glandulosa*. Each of these three groups of plants has been eminently suited to the purpose for which it was used. The usefulness of these materials for discovering

basic laws governing relationship and distribution of organisms in a region of climatic and topographic diversity, and the broad scope of the coordinated investigations, are unique features of this program.

It is an obligation to bring this material to prompt publication. The two parts of "Experimental studies on the nature of species" published by the Carnegie Institution, one as publication 520, on environmental influence, and the other as publication 564, on amphiploidy and autoploidy, deal with two phases of our program. The intervening field is to be treated in publications on the evolutionary dynamics of the Madiinae, on the climatic races of *Achillea*, and on the genetics of ecotypes.

The grass program, which extends the field to speciation in a group of asexually reproducing (apomictic) plants, was largely built on the principles learned in these still unpublished investigations. It has had three interlocking objectives. One is the development of improved range and forage grasses. At best, the necessarily limited output of such materials can be expected to contribute only a small part to the solution of the very complex problem of improving the range lands. Once the utility of these methods of producing superior grasses is demonstrated, this phase of the program obviously belongs to agencies other than those devoted to basic research.

The second and more important objective is the development of new principles in the practical breeding of range and forage grasses, in this case combining species fitted to very contrasting environments to obtain hybrids with greater tolerance, and speeding the production of new forms by utilizing nonsegregating hybrids.

The third objective is to arrive at an understanding of the laws that govern the evolution of forms in a group of apomictic

organisms. The other two objectives depend on this one, the attainment of which is clearly within the domain of basic research.

Our plan is to proceed with the preparation for publication of the Madiinae investigations, the selection experiment, and the studies on climatic races, while continuing the experimental work on *Poa*. Under this arrangement, facilities at the stations now partially vacated by the other programs become available for *Poa*, the data on which can be assembled while the other records are being analyzed.

#### GUEST INVESTIGATIONS

Dr. Th. Dobzhansky, Research Associate of the Carnegie Institution from Columbia University, utilized facilities at the Mather transplant station during the summer of 1945 for experiments related to the genetics of native populations of *Drosophila pseudoobscura*. Dr. G. L. Stebbins, Jr., of the University of California, also spent some time there during the summer, analyzing wild populations containing intergeneric and interspecific hybrids of *Agropyron*, *Elymus*, and *Sitanion*. Mather is strategically located for studies

on the distribution of plants, for forms common to higher and lower elevations, and of northern and southern distribution, frequently grow together here and a number will hybridize.

Professor W. E. Lawrence, of Oregon State College, spent two summer months during 1945 at the laboratory at Stanford studying the geographic distribution of *Achillea* throughout the Pacific coast states. As no thoroughly dependable morphological characters have been found to distinguish all forms of *Achillea borealis* Bong., which is hexaploid, from *A. lanulosa* Nutt., which is tetraploid, the only safe way of determining their distribution is to count the chromosomes. In California, the hexaploids extend from the coast to the foothills of the Sierra Nevada and have developed three or four major ecotypes over this area. Higher in the Sierra and eastward they are replaced by the tetraploids. Lawrence finds that in Oregon the tetraploid presses to within a very short distance of the coast, replacing all hexaploids inland, but leaving room for the maritime ecotype of the hexaploid species, which extends north to the coast of Alaska and the Aleutian Islands.

#### DESERT INVESTIGATIONS

FORREST SHREVE

Shortly after the establishment of the Division of Plant Biology a program was formed for a regional investigation of the desert areas lying in Arizona, southeastern California, and the Mexican states of Baja California and Sonora. This is a sharply marked area with essential unity in its climatic and biological conditions. In geographical and botanical literature it has long been designated as the Sonoran Desert. The Desert Laboratory of the Institution was located on the inner edge of this area and about midway between

its northern and southern limits. The Sonoran Desert program provided for a complete enumeration of the higher plants, more exact determination of their areas of distribution, and fuller knowledge of their habitat requirements and ecological behavior, as well as for a study of the types of vegetation found in the area, their distribution and relationship, and their relation to the differences of climate and soil that were known to exist in the more widely separated parts of the area of 126,000 square miles.

Field work was begun in 1932 and carried on actively for five years, being supplemented later by several visits to areas of importance which had not previously been readily accessible. Work on the vegetation was carried out by Dr. Shreve and Dr. T. D. Mallery, and the study of the flora was in the hands of Dr. I. L. Wiggins, of Stanford University. Large plant collections were made by Dr. Wiggins and he has devoted much time to the study of material collected in the area by early workers. Because of the fact that there has been no previous compilation of the flora of the Sonoran Desert or the Mexican parts of the area, it has been necessary for Dr. Wiggins to make a critical study of almost every group of plants found there. The adoption of a natural rather than a political area has also made it necessary to determine the precise locality in which each of the older collections was made.

The principal differences of vegetation in the several parts of the Sonoran Desert are chiefly attributable to restriction of rainy periods in Baja California to the winter and early spring months, the occurrence of biseasonal rains in the northern parts, and the increasing prevalence of summer rains toward the south. The vegetation of Baja California is marked by the occurrence of several common large plants which are either confined to that peninsula or found only very locally on the mainland. The size and unique character of some of these plants, as *Idria*, *Pachycormus*, *Yucca valida*, and *Pachycereus Pringlei*, have given Baja California a reputation for unique vegetation which is scarcely borne out when consideration is given to the less favorable habitats and to the very large number of characteristic plants which are common to this and other parts of the Sonoran Desert. Where the desert borders the Pacific coast it is of a

type very distinct from that found inland, but it enjoys extremely little amelioration of the arid conditions through its proximity to the sea. The almost constant strong ocean winds join with the aridity in causing a very low and open plant covering.

The region of biseasonal rainfall is one in which the control of soil moisture by topographic conditions is marked. The broad plains support a very uniform shrubby vegetation which is low in stature and made up of a small number of species. The coarser soil of bajadas, pediments, and the slopes of hills and mountains supports vegetation which is taller, more dense, and made up of a much larger number of species. The southern part of this desert area, lying in the state of Sonora, and the inner edge of the area, lying near the foothills of the Sierra Madre, support a heavier vegetation than is found in the north. The flora of the southeastern part of the Sonoran Desert is greatly enriched by the occurrence of many trees and shrubs which here reach their northern limits. A few of these are characteristic plants of the thorn forest which extends south from the southern edge of the desert. In this region the rainfall is greater than it is in the Colorado and Gila valleys, and its increase with increasing altitude is greater.

The Sonoran Desert program has, in effect, been an extension of the earlier work of the Desert Laboratory, carrying the investigation of the Tucson region to the distributional limits of the plants which had been studied there, and using the knowledge of the plants and conditions of the Tucson area as aids in interpreting the ecological features of the more remote parts of the desert area.

In 1937 the program of desert work was extended to include the more elevated areas lying east of the continental divide in western Texas and the Mexican states of Chihuahua, Coahuila, Durango, Zacatecas,

and San Luis Potosí. This area has been designated the Chihuahuan Desert, although field work has revealed that the most characteristic part of the area, and the one in which the agencies of aridity have apparently been longest at work, lies in the state of Coahuila.

The Chihuahuan Desert lies mainly above 3500 feet in elevation and includes some very arid areas together with others in which there is summer precipitation approaching that of the central part of the Sonoran Desert. The winter temperatures are much lower than those in the coldest parts of the Sonoran Desert. The Chihuahuan Desert is distinguished by the occurrence of numerous large and small undrained basins which have either a central saline playa or a deep soil with a heavy stand of coarse grass, and by the prevalence of limestone outcrops and hills of a type which erodes very slowly under arid conditions.

The study of the flora of the Chihuahuan Desert has been carried on through the cooperation of Dr. I. M. Johnston, of Harvard University, who had already done considerable work in the deserts of Chile and Argentina. Dr. Johnston made large collections between 1938 and 1941, and has been favorably situated at the Gray Herbarium for study of the older collections from northern Mexico. He has detected a relatively large number of new species in the area, has thrown new light on the floristic affinities of the flora of the basins and mountains of northern Coahuila, and has found critical study and revision necessary in several groups of plants. Dr. Johnston has published papers embodying descriptions of new species, and in 1943 and 1944 published five installments of an annotated list of the plants of Coahuila and adjacent states, covering the families from the Polypodiaceae to the Nyctaginaceae.

The distribution of vegetation in the Chihuahuan Desert is mainly controlled by the character of underlying rock and soil and by the major topographic features. Only at elevations of 1000 to 2000 feet above the surrounding plains does the influence of climatic conditions become important in differentiating the vegetation. In spite of floristic differences, there is a strong similarity between comparable situations in the northern and southern parts of the desert. Trees are far less frequent than in the Sonoran Desert, and shrubs and such semishrubs as *Atriplex* are characteristic. Large cacti are relatively uncommon, but small ones are extremely abundant. Extensive areas have open or heavy stands of *Yucca* or *Dasyliion*. Also the smaller semisucculents *Agave* and *Hechtia* are found in extensive stands, particularly on limestone. In all parts of the Chihuahuan Desert above 5000 feet there are many areas with an open sod of perennial grasses.

There are no parts of the Chihuahuan Desert in which the ground is as thickly covered with diversified groups of striking plants as in many localities in Sonora and Baja California. Only in Zacatecas and San Luis Potosí does the occurrence of tall yuccas, *Acacia Farnesiana*, and large platyopuntias and agaves give striking evidence of the somewhat ameliorated conditions which exist along the southern edge of the Chihuahuan Desert.

The preparation of material for companion publications on the flora and vegetation of the Sonoran and Chihuahuan deserts has made progress during the past three years, in spite of other urgent demands on the time of the participants, and the ultimate completion of the results of the projects should be possible within the next two years.

## PALEOBOTANY

RALPH W. CHANEY

Completion of the study of an Eocene cactus by Dr. Chaney is the only concrete yield of the period during which he has been engaged upon an emergency war assignment. Modern members of the Cactaceae are highly specialized; in the case of the tribe *Opuntieae*, which the fossils closely resemble, this specialization of vegetative structures makes possible their existence in arid or exposed environments. Discovery of similar plants in rocks assigned to the Eocene epoch, when modern flowering plants were first becoming dominant and widespread, is therefore of interest as indicating an early development of this structural adjustment to desert conditions. This record of a prickly-pear type of cactus, to which the generic name *Eopuntia* has been assigned, extends the known age of the Cactaceae back some fifty million years to the early part of the Tertiary period, the period preceding that in which we live.

The Green River formation of Utah and adjacent states contains an abundance of plant remains. Most of the conifers and angiosperms are preserved as impressions, which show the surface characters of leaves, stems, and fruits in great detail but supply little information regarding their internal structure. Our specimens of *Eopuntia*, representing stem joints and attached fruits, show on their surfaces linear markings which are not characteristic of similar living cacti. It is therefore particularly fortunate that one of the stem joints has been so preserved that not only the external but the internal characters may be observed. When studied from within, these linear markings are seen to represent vascular strands of a siphonostele, a type of stem still occurring in certain primitive genera of the Cactaceae, but superseded by

the more specialized dictyostele in modern *Opuntieae*. These earliest members of the cactus family, though having the flattened, fleshy stems of living prickly pears, were at an unspecialized level of vascular development consistent with their great antiquity. In several features of their fruits, the ancient cacti of Utah also show more generalized structures than their modern descendants. The bases of the fruits are narrowed and stemlike, vascular tissues are well developed, and areoles are numerous on their distal ends. These characters of the fruits, like the stelar structure of the stem joints, suggest an ancestral relationship with modern *Opuntieae*, and an intermediate position between *Opuntieae* and the more primitive tribes *Pereskiaeae* and *Cereeae*.

The Green River flora as a whole contains many genera which now live in regions characterized by warm-temperate climate, with well defined dry seasons. Such an environment appears to have been present in eastern Utah during the Eocene epoch, and to have provided living conditions suited to this oldest known cactus.

The current eruption of Parícutin is providing an opportunity to continue the study of conditions under which many fossil plants have been preserved in the western United States. Widespread vulcanism during the Tertiary period provided the topographic setting and the sediments which facilitated the burial of stems, seeds, and leaves of ancient trees and shrubs, and their subsequent transformation into fossils. A clearer picture of the past can be drawn if we have an understanding of factors concerned in the burial and preservation of plant remains in contemporary deposits. Under the combined auspices of Princeton University and the Carnegie In-

stitution of Washington, Dr. Erling Dorf has spent a month at Parícutin volcano, in a study of the occurrence of plant remains in volcanic sediments. His preliminary report indicates that (1) leaves, stems, and fruits of plants buried during the eruption have been little if any altered as yet; (2) there is abundance of remains of pine and oak, but other trees such as alder, linden, and cherry are poorly represented although they are numerous in the region; (3) plant

remains have been well preserved only where buried close to their parent trees or shrubs; (4) subaerial ash deposits contain more abundant and better-preserved material than stream and lake deposits; (5) these deposits are already being destroyed by erosion; (6) the best situation for the ultimate preservation of the record of this Mexican forest will be in valley ash deposits buried by lava to protect them from erosion.

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## DEPARTMENT OF EMBRYOLOGY

*Baltimore, Maryland*

GEORGE W. CORNER, *Director*

This annual report, the fourth to be submitted since the entry of our nation into the war, is accompanied by the smallest review of published work since the Department of Embryology first got well under way. Two members of the regular staff of investigators have been away on war duty. A group of workers normally active in peace times, consisting of visiting investigators, temporary members in the status of fellows, and local scientific workers making use of the laboratory's facilities, has been almost completely scattered by the war. The Director and other members of the staff have been distracted by emergency duties and by the general disturbance of the times.

The small output of the year, in published research, does not however represent all the activities of the Department. The accumulation and preparation of human embryos has continued, and in fact the year has seen a notable growth in the number of well preserved embryos cut into perfect serial sections by Dr. C. H. Heuser, Curator of the Embryological Collection, and his technical assistants. In an effort to provide Dr. G. L. Streeter with ample material for his special project described below, a score or more of embryos of the fourth and fifth weeks were prepared for study. The specimens thus newly made available for morphological research, representing the period when many of the important organs begin to take form, make a permanent addition to our resources.

Mr. O. O. Heard, the senior modeler, working in collaboration with Dr. Heuser, devoted much time to the perfection of a new technique of microtomy intended to

reduce the distortion of tissues caused by the pressure of the microtome knife. His new knife, circular in form, is made to rotate as it passes through the tissues and thus produces a slicing cut. Considerable mechanical effort is necessary to produce a truly circular knife and to keep its edge in good condition. In the course of this work Mr. Heard has acquired a great deal of information, both practical and theoretical, about the nature of a useful knife-edge for microtomy. This will doubtless be published in due time and is now being put to use. Other members of the staff have been able to maintain their research programs along the lines mentioned in previous Year Books, with results that will be publishable in due course. We have continued to put about half the facilities of the monkey colony at the disposal of a research group from the Johns Hopkins University School of Hygiene, in the conduct of a study in tropical medicine requiring the use of monkeys under the skilled care which our animal-house staff is qualified to give.

Dr. Louis B. Flexner, who has been Technical Aide to the Committee on Aviation Medicine of the National Research Council, has been released from most of the demands upon his time made by that work, and will resume on a larger scale than before his studies on the physiology of developing tissues. Dr. S. R. M. Reynolds, major in the Army Air Forces, has been released from the army. There are hopeful signs that the group of investigators outside the formal membership of the staff will soon be reconstituted. Post-war plans of the Department involve no

large deviation from the program which was set forth by the Director in the annual report for 1940-1941 (Year Book No. 40).

The war has delayed the work but has not altered the fundamental problems of human development.

### EMBRYOLOGY AS A COOPERATIVE SCIENCE

During the period, now ending, of national concentration for war, scientists have found themselves called upon as never before for cooperative action. A trend, created by the needs of modern science and already noticeable in recent years, toward group research by associates trained in different branches has been greatly accelerated by the war. The public is now learning through the newspapers and magazines of the group projects that sprang into existence under such organizations as the Office of Scientific Research and Development and the National Research Council. Some of the practical achievements of group research are already apparent. Among the gains brought about by this war, in partial compensation for its destruction and misery, surely not the least is this cross-fertilization of the various sciences, which results not only in immediate practical advantages, but also in new thinking about fundamentals. The synthesis of ideas thus achieved is not lost even if in times of peace the pendulum swings again necessarily toward individualistic research.

Professional scientists are therefore in a mood, at present, to take stock of the services their respective branches may render to others. A few reflections on this question, as concerns a laboratory of mammalian embryology, may be useful in forecasting our own work in the future.

The science of the development of the higher animals, and especially of man, has necessarily been largely descriptive and has mostly dealt with events so intricate, so much unlike the things man can do with his hands and mechanical tools, as to ban-

ish any thought of controlling them. The embryologist could only observe, depict, and describe, although the phenomena thus revealed have been of such profound significance as to claim the attention of able minds to embryology as a pure science. Embryology could not give immediate birth to applied science as physics gave birth to locomotives, flight, and electronic devices. Its chief practical service, rendered to the art of the physician, has been to provide a background of explanation and understanding for many otherwise puzzling facts of normal anatomy as well as of structural anomalies and defects. This service is often so subtle that it is not appreciated by ultra-practical minds. Presumably an operation, for example for congenital hernia or cleft palate, could be done successfully without knowledge of the embryology of the region; but the surgeon who has the responsibility of repairing such lapses of development, if he understands how they came about, operates with added assurance and comfort of mind. This is well understood by the wisest surgeons, as is evidenced by the time many of them have spent on embryological studies. To cite a case close at hand, we are preparing to publish in an early volume of the Carnegie Contributions to Embryology a painstaking investigation of the development of the arteries of the brain, made by Dorcas H. Padget, of the staff of the distinguished neurological surgeon Walter E. Dandy. Dr. Dandy's interest in this subject was aroused because he observed anomalies of the cerebral arteries at the operating table and he thought it worth while to subsidize a study of their origin.

The staff members of the Department of Embryology, like embryologists in other cities, are not infrequently called to the hospital clinics to take part in the scientific analysis of cases involving embryonic defects. Whether or not the embryologist contributes to a cure, the patients are fortunate to be in the hands of physicians who want to understand their problems from the most fundamental aspect.

At any moment, of course, the facts of a so-called "pure" science may suddenly be found to have practical importance. This has been strikingly true of one division of mammalian embryology: the investigation of the reproductive cycle, i.e., the integration of function of ovaries, uterus, and other parts of the female reproductive tract, by which the maturation of the ovum, its discharge from the ovary, its fertilization, transportation to the uterus, and implantation are timed and coordinated. About the beginning of the present century the newly developing study of endocrinology and that of the reproductive cycle were brought together, with the result that the half-century has seen an enormous increase of knowledge of the hormonal control of reproduction, with practical results that are already impressive, if measured by the number of pages in the medical journals on this subject and the investment of the pharmaceutical firms in the manufacture of steroid hormones. The staff of our laboratory has already taken a part in this advance and we shall continue to work in the same field.

There are several aspects of embryology in which a similar cooperative attack is under way or impending. In recent years there has been a great advance in knowledge of the enzymes in animal tissues, and of other chemical and physical systems controlling such essential functions as tissue respiration and the intracellular metabolism of various organic substances.

Some of these discoveries have gone so far as to localize the enzymes under the microscope, as for example the new techniques of Gomori for visualizing the phosphatases. The chemical processes of cell life are being worked out. The developing embryo offers an especially favorable opportunity for studying the chemical functions of specific tissues, for as the embryo grows, new organs and tissues make their appearance. Applying the new techniques to the embryo, it will be possible in many cases to associate the appearance, the peak activity, and the disappearance of an enzyme or other metabolic chemical compound with the unfolding organic structure. In the long run we shall thus approach a full understanding of the physicochemical means by which the organs and tissues of the body are developed and differentiated from the simpler constituents of the fertilized egg. As this kind of investigation develops, the chemical embryologist will find himself in cooperative relation with other students of growth, and especially with investigators of abnormal growth, i.e. cancer and other tumors. No line can be drawn, in fact, between normal growth as in the embryo and infant on the one hand, and abnormal growth on the other. Whatever is learned from one will help in understanding the other. We have long since had an example of this fact in the work on cell growth in tissue cultures, carried on in our laboratory by Dr. W. H. Lewis and Dr. M. R. Lewis. Begun as a way of analyzing normal cell growth and development, their program became closely associated with cancer research.

Another phase of mammalian embryology in which, one may venture to predict, there will soon be notable progress through cooperation between the sciences is that of teratology, the lore of embryonic abnormalities. It has been part of our

departmental routine to preserve and study anomalous and defective embryos and to render diagnostic service to physicians as far as current knowledge goes. Better knowledge, based on experiments, has had to wait for the results of work on lower animals. Experiments on accessible embryos like those of fish, amphibians, and birds, intended to produce defects and anomalies, are a century old and have taught us much about the susceptibility of early embryonic tissues to harmful environmental conditions, e.g. excessive cold, heat, defective oxygenation, deleterious chemicals, etc. The advent of genetic analysis has taught us how defective genes can also produce disturbances of development. It has been difficult to reach the well protected embryos of mammals with such experimental weapons, but progress is being made, and a science of experimental teratology in mammals is probably not far off. The attention of physicians and even of the lay public has recently been directed to the damage to human infants in utero produced by certain disorders of immunity caused by the "Rh" factor, and by the occurrence of the virus disease rubella (German measles) in early pregnancy. In our laboratory we have already begun an effort (admittedly unsuccessful thus far) to analyze the rubella problem by experiments on monkeys.

Enough has been said to show that investigators of the embryology of man and the higher mammals not only are following a so-called pure science, but are more and more in a position to contribute their knowledge to cooperative study of problems that are of vital practical importance. During the war it was frequently necessary to explain to selective service boards and similar public officers (people not at the moment officially interested in theoretical science), in the small blank space of a questionnaire, what the Department

of Embryology considered itself to be doing for the national effort. The statement, which fortunately seemed acceptable, was that we are carrying on our share of the research on which the maternal welfare and "better baby" programs are based. This explanation, of course oversimplified, will serve to show that we are not unmindful of our opportunity to render service to the public through medical application of embryology. There will, however, always be a place in this Department, especially in the unharassed times of peace, for research workers, if such there be, who disregard all thought of application and usefulness to study the development of the human body simply because it is ineluctably fascinating. If in some future day the embryologists learn how to get at the smallest units of life and split and recombine them, as physics has reached inside the atom, the resulting changes (which will be as cataclysmic as the atomic bomb, for good or evil) will have resulted from the work of the cloistered theorists of earlier years.

Discoveries about the embryonic development of man and the other primates place the embryologist in cooperative relationship also with students of biological theory, philosophy, and even religion. The relation of man to the other animals is greatly illuminated by the study of his development. This is an old story which had its lurid chapters in the days of conflict over evolution. Now that the animal affinities of man are accepted, the embryologist is able to make a sober contribution to the details of primate evolution. Mammalian embryos not only possess incipient anatomical organs and systems like those of adults, which may be studied for evidences of resemblance and dissimilarity as in ordinary comparative anatomy; they also possess a set of organs not present in the adult, namely, the placenta and the

embryonic membranes and cavities of the chorion, amnion, allantois, and yolk sac. These organs differ extraordinarily from species to species, and thus they are of very great importance to the investigator who seeks to know how one animal or group of animals is related to another. It happens that in man and the other primates there are enough differences in the placentas and membranes to give us light on the old Darwinian question, whether man's eldest living relatives are to be found among the anthropoid apes or the mon-

keys. Given time, means, and sufficient ingenuity, we have much to learn from an extension of our program of embryological study, especially the study of the earliest stages of embryonic development, to the infrahuman primates of Africa, Asia, and America.

The understanding of man's place in the animal world, gained from such studies as these in association with other branches of comparative zoology, necessarily influences the whole structure of human education, lawmaking, and philosophy.

## RESEARCHES, COMPLETED AND IN PROGRESS

### DEVELOPMENTAL STAGES OF HUMAN EMBRYOS

Dr. G. L. Streeter continues actively his program of classification of human embryos. This undertaking was fully explained in Year Book No. 42. Its aim is the description and depiction of human embryos in such manner that successive stages of development can be recognized by obvious characteristics, both external and internal. By this means embryologists will be able to indicate the stage of development of any embryo by reference to Streeter's numbered stages, thus obviating all sorts of difficulties inherent in the comparison of objects which differ, as they develop, by so many variables at once. The descriptions of stages XV to XVIII are now well advanced and will be published in volume XXXII of the Contributions to Embryology.

Stage XV, including embryos of age estimated as 30-32 days, is characterized by detachment and closure of the lens vesicle. At this and the two following stages, the development of the bronchus is useful for the comparison of sectioned embryos; in stage XV the secondary bronchi are distinguishable as swellings on the

primitive bronchi. Stage XVI (32-34 days) is readily detected by the appearance of the first retinal pigment. The secondary bronchi are clearly recognizable. In stage XVII (34-36 days) the retina is heavily pigmented. The secondary bronchi begin to branch. The calyces of the renal pelvis appear. In stage XVIII (36-38 days) the first semicircular canals of the internal ear (vestibular apparatus) are seen. Jacobson's organ is distinct in the nasal region.

The essence of Dr. Streeter's plan is thus to select, describe, and depict characteristic structural details at each stage. A fact thus revealed, perhaps not unexpected theoretically, but very striking as brought out by this research, is the high correlation between the various organs of the body as to time of first appearance and stages of development. If, for example, in a well preserved embryo the eyes are just beginning to show retinal pigment, then it is certain that secondary bronchi will be present in the lungs. If any organ lags behind, there is something wrong, and this is generally evidenced by multiple deviations. In a brief review of Dr. Streeter's work only a few of the characteristics which he has studied can be mentioned;

his successive chapters must be read to appreciate the march of developmental events.

#### VERY EARLY HUMAN EMBRYOS

The collection has been enriched by the receipt from our collaborators Dr. Arthur T. Hertig and Dr. John Rock of several embryos of the late second and the third week, in addition to those reported in previous Year Books. These valuable specimens have been sectioned by Dr. C. H. Heuser, aided by the technical staff, and together with ample photographic records are preserved in the collection of the Department.

#### THE RATE OF ABNORMALITY IN EARLY EMBRYOS

This past year has seen the completion of preliminary studies by Dr. Hertig and Dr. Rock, at the Free Hospital for Women in Brookline, Massachusetts, on a series of one hundred fertile married women on whom a therapeutic hysterectomy was performed in known calendar relation to the next expected menstrual period. The investigation was supported by the Carnegie Corporation of New York, by the Carnegie Institution of Washington through this Department, and by the Milton Fund of Harvard University. The surgically removed uteri were carefully searched for the presence of young fertilized ova, either free in the uterine cavity or implanted on the endometrium. During the seven years of this study, nineteen such specimens were found. These form the Hertig-Rock collection of very early human embryos, already well known to readers of these annual reports, in which many of the individual specimens have been discussed as they were added to the Carnegie Collection in this laboratory. Several of them have been published in full and they are

already beginning to find their way into the textbooks of embryology.

Dr. Hertig and Dr. Rock, reviewing their work for this report, state that the nineteen embryos range from a specimen 4 days of age (a segmenting ovum found free in the uterine cavity) to one 16 days of age, a well imbedded ovum with early, simply branched chorionic villi. Eleven of the nineteen specimens are judged to be perfectly normal and encompass the stages of embryologic development from that of a recently implanted blastocyst (7½ days) to that of an early villous ovum (16 days). The remaining eight are pathological in one way or another, their abnormalities including such diverse factors as faulty segmentation, absence of the embryonic disk, extreme hypoplasia of the trophoblast, and shallow implantation of an otherwise normal ovum.

It is apparent from these figures that the index of fertility in married women of proved fertility, with at least one recorded coitus during the estimated time of ovulation preceding the hysterectomy, is 19 per cent. Equally apparent is the fact that a high proportion, 42 per cent, of these early pregnancies would probably have failed to reach term. Indeed, it is doubtful whether the abnormal segmenting ovum of 4 days would have implanted and, if it had, whether it would have caused the next expected menstrual period to be missed. Of the seven pathological ova that were implanted, it is doubtful whether the two most abnormal forms would have more than briefly delayed the next expected menstrual period. Thus it is apparent that many fertilized human ova, as is the case with lower animals, are destined to abort before the fetal stage is reached. Certainly, many of the abnormal forms encountered in this study have their pathological counterparts in ova spontaneously aborted by patients during the early months of preg-

nancy. Therefore, these early abnormal forms of pregnancy serve to teach us something about the pathogenesis of human abortion, a subject about which little is known at present. This is so because the specimen from a spontaneously aborting patient is relatively so mature that it is impossible to trace accurately the sequence of events leading to the premature expulsion of the nonviable ovum.

During the past year, two of the specimens mentioned above were recovered from the last thirteen patients of the series. Both specimens were abnormal with respect to their embryos, although the chorions were normal. The younger specimen (Carnegie no. 8299), estimated to be about 12 days of age, shows a disoriented germ disk (embryo), of which the cephalic end points directly toward the trophoblast, while the caudal end, at the site of the potential body stalk, is free in the chorionic cavity. It is unlikely that a good body stalk or umbilical cord would have formed. This may be the early stage of the frequently found type of pathologic ovum which invariably aborts and whose embryo is either nodular or stunted and is attached to the trophoblast by a defective body stalk.

The older specimen (Carnegie no. 8290), an early villous ovum about 13 days of age, likewise shows a serious defect of its embryonic disk, the primitive ectoderm being disoriented with respect to the underlying primitive endoderm and its associated yolk sac. It appears as though the dorsal part of the premature embryo had slipped horizontally with respect to the ventral part, an abnormality which would probably interfere with any proper axial differentiation of the future embryo.

Continuing their report, Dr. Hertig and Dr. Rock state that regardless of whether their tentative interpretation of the relation of such defective early embryos to

subsequent defects in the aborting ovum is correct or not, the fact cannot be gainsaid that here are a series of intrinsically defective ova whose environment is apparently normal. Hence this series offers additional evidence of such a condition as "germ plasm defect," unsatisfactory and all-inclusive though the term may be.

During the past year, the detailed description of one of the 7½-day ova and the 9½-day ovum (Carnegie no. 8020 and no. 8004) has reached galley-proof stage, and its appearance in the Contributions to Embryology is expected in the near future. In addition, plastic sheet reconstructions of two ova (Carnegie no. 8155 and no. 8171) have been prepared in anticipation of completing a detailed description of these two specimens for early publication.

#### ATTEMPTS TO FERTILIZE HUMAN OVA IN VITRO

Dr. John Rock reports that during 1944-1945 he has continued his efforts to fertilize and initiate cleavage of human ovarian eggs. This work, primarily supported by the Milton Fund of Harvard University, has also depended upon facilities provided for the discovery of early human embryos (discussed in the previous paragraphs) supported by the Carnegie Corporation of New York and more recently by the Carnegie Institution of Washington through the Department of Embryology.

A year ago (see bibliography), Dr. Rock and his associate Mrs. Menkin reported on the fertilization of three such eggs. During the past year, 103 follicular eggs in the preovulatory phase have been recovered from operative patients. The eggs were cultured in serum and 76 of them were exposed to spermatozoa, but none were successfully fertilized. Forty-nine of the eggs were cultured, before exposure

to sperm, in serum to which had been added a small amount of hyaluronidase. English investigators (Rowlands and McLean) had found that this enzyme would break down the gel of the corona radiata, allowing the sperm to penetrate the egg. Thus far, Dr. Rock has not found this to be of much assistance, but he plans to try a larger variety of techniques.

#### EMBRYOS OF THE BABOON

In an earlier paragraph of this report it has been pointed out how we may get clues as to the evolution of man by comparison of the embryos of the various primate species with one another. The value of such comparative study has long been recognized by the Department. It possesses, through the efforts of Dr. C. G. Hartman, a noteworthy collection of embryos of the rhesus monkey described in a recent monograph by Dr. C. H. Heuser and Dr. G. L. Streeter. A beginning has been made also with respect to anthropoids, two early embryos of the chimpanzee being in the collection. In 1942 the Department enjoyed a long visit from Dr. Joseph Gillman, of the University of the Witwatersrand, Johannesburg, South Africa. Dr. Gillman possesses extensive knowledge of the breeding habits and physiology of reproduction of the baboon (*Papio porcarius*), and required only more extensive facilities for collecting, housing, and breeding animals to enable him to collect early embryos. As the result of plans developed during his visit, the Trustees of the Carnegie Corporation of New York made a grant late in 1942 from their British Dominions and Colonies Fund (to be administered through this Department) to provide facilities for such an enterprise. The effort has now begun to yield results, for during the year 1944-1945 Dr. Gillman has sent five embryos of *Papio porcarius*,

all younger than one month old. These are being photographed and sectioned, and promise to yield much information about early placentation and the formation of the embryonic membranes. It is a most interesting fact, in view of the studies of Hertig and Rock, mentioned above, on the proportional incidence of early abnormality of human embryos, that one and possibly two of the first three Gillman baboon embryos are pathological. Such early abnormalities are as valuable, in their way, as normal specimens, provided a sufficiently large series can be assembled to permit proper comparison of normal and abnormal types.

#### PHOSPHATASE IN THE OVARY; FATE OF THE THECA INTERNA

Dr. George W. Corner has completed the preliminary stages of an investigation of the distribution of the enzyme known as alkaline phosphatase in the cytoplasm of ovarian cells of various species. This enzyme, as its name indicates, has the property of splitting phosphate ions from the compounds of phosphoric acid, in an alkaline environment. It is widely distributed in the organs and tissues of the body. In bony tissue it is obviously concerned with the metabolism of calcium by its action on calcium phosphate. In tissues like the ovary its function is less obvious; probably it is concerned in the metabolism of phospholipids. Dr. Corner's attention was turned in this direction by a recent publication of the Chicago histopathologist Gomori, who devised a method of demonstrating the presence of alkaline phosphatase in microscopical sections. Gomori included the ovaries of a few species among the tissues which he studied in cursory fashion. Because he found that in some animals the theca interna and the membrana granulosa of the Graafian follicle

differ in their content of alkaline phosphatase, there seemed to be a possibility of using the method to trace the fate of the theca cells in the formation of the corpus luteum, and thus to contribute to the solution of an old problem.

In brief, the result was that in the domestic sow the fate of the theca interna can be clearly followed, because the theca interna is rich in phosphatase and the granulosa lacks it. The theca cells, thus traced, persist throughout the formation of the corpus luteum and become scattered among the granulosa lutein cells. This confirms a description of the origin of the corpus luteum of the sow, published by Corner in 1919, which has been disputed. In the several other species studied, all possible variations of the distribution of phosphatase between theca interna and granulosa are found; in the rhesus monkey, for example, both these layers are rich in phosphatase; in the rabbit the enzyme is plentiful in the granulosa and absent from the theca interna. The method cannot therefore be used in these species to trace the theca cells after rupture of the follicle. This puzzling difference between species, however, may ultimately afford an explanation of the function of the enzyme, by revealing the association between phosphatase and other constituents of the ovarian cells.

#### INJURIOUS EFFECT OF LIGHT UPON DIVIDING CELLS IN CULTURES CONTAINING FLUORESCENT SUBSTANCES

Certain substances have the property of fluorescing, that is, of emitting radiations when themselves radiated, for example with light rays. The emitted radiation is generally of longer wave length than the exciting radiation, and is thus of different color. This phenomenon accounts for the peculiar glow of solutions of eosin and

the bluish color of ordinary machine oil seen in strong daylight. It is more vividly displayed by various fluorescent substances when observed in the dark under the invisible rays of ultraviolet light. It has long been known that animal and plant tissues containing fluorescent substances are injured by light. A few years ago renewed attention to this subject was stimulated by the discovery that cancer cells growing in tissue cultures containing eosin were more sensitive to light than normal cells growing in the same cultures.

Dr. Margaret Reed Lewis has analyzed this phenomenon of photosensitivity of living cells in the presence of fluorescent substances by growing chick embryo cells in culture media containing various fluorescent substances, namely chlorophyll, dibenzanthracene, methylcholanthrene, eosin, and neutral red. Attention was centered on the dividing cells because it has been found previously that dividing cells in growing cultures are more sensitive than resting cells. Dr. Lewis found that the fluorescent substances named above, when added in suitably dilute amounts, were not toxic to the process of cell division as long as the cultures were kept in the dark, but when a strong light was passed through the cultures the cells quickly became damaged. The mitotic spindles and chromosomes and also the cytoplasm were injured. If the exposure to light was prolonged, the cells died. Cells showing only a slight injury were able to recover when the cultures were returned to the dark.

These effects were apparently not due to the light emitted from the activated fluorescent substance, for the cells continued to grow normally when irradiated by light that had been passed through eosin or neutral red solutions outside, but very close to, the culture slides. It appears that the cells were damaged by changes

brought about in the medium during the activation of the fluorescent material.

#### INDUCTION AND TRANSPLANTABILITY OF SARCOMATA IN RATS

Dr. Margaret R. Lewis, working in collaboration with Dr. Helen Dean King at the Wistar Institute of Anatomy and Biology, has completed an extensive study of the biological factors governing induction and transplantation of malignant tumors (sarcomata) in rats. The two workers made use of the carcinogenic substances dibenzanthracene, benzpyrene, and methylcholanthrene. These substances, when injected subcutaneously into rats, produce cancer of the connective tissue, that is to say, sarcoma. The experiment involved such injections into large numbers of rats of various genetic strains, and subsequent transplantation of the induced tumors into other rats of the same various strains. The object of the work was to discover whether the differences between the strains, evidenced in physical characteristics, growth rate, behavior, and reaction to stimuli, would affect the character and growth of the induced tumors or of the implanted tumor grafts. The strains used were the "King A" inbred albinos of the Wistar Institute, gray Norway rats of the Wistar Institute, three crosses between these, and nine different mutant strains of diverse origin. In all, nearly 10,000 rats were used.

Every one of the rats in thirty litters from the fourteen strains survived the carcinogenic injection and developed a sarcoma. The tumors thus produced behaved somewhat differently under different circumstances of sex and strain; they developed earlier in males than in females, and grew more slowly in gray Norway rats than in the other strains.

The transplanted tumors also behaved differently under different circumstances.

They were, as would be expected, more transplantable to rats of their own strain of origin than to the other strains. Tumors that originated in the highly inbred King A rats were 100 per cent transferable to rats of the same strain and to two of the crosses with Norway rats. When inoculated into the other strains, however, they did not behave alike. Some grew in some of the other strains, some did not; in other words, there was a tendency to be strain specific. Tumors that originated in rats of less inbred strains grew much less frequently in the rats to which they were transplanted. One strain, the "curly" mutant, was highly resistant to the growth of sarcomata transplanted from rats of its own and of other strains. Tumor grafts grew faster when implanted into young rats than into old rats. Growth of the grafts was not influenced by coat color.

In summary, the sarcomatous malignant tumors of rats induced by carcinogenic agents proved to be subject, as regards their growth, to biological influences which are associated with different hereditary history (strain) of the rats into which they are transplanted.

#### FAILURE OF PURIFIED PENICILLIN TO RETARD SARCOMA

In March 1944 Mr. Ivor Cornman, who had been working at the Wistar Institute under the guidance of Dr. M. R. Lewis, published the finding that the growth of sarcoma tissue in tissue culture is inhibited by penicillin. The penicillin used in his experiments was a partially purified sample. Dr. M. R. Lewis proceeded to try the effect of the sodium salt of penicillin upon sarcoma, using mice of the Bagg inbred strain implanted with a sarcoma native to the strain. Ample doses of the penicillin, which was highly purified, failed to inhibit the growth of sarcoma *in vivo*. Dr. Lewis

next tested penicillin upon sarcoma cells growing in tissue culture, using both a highly purified colorless sodium salt and a less pure yellow sodium salt. The latter, in the higher of the concentrations used, killed the tumor cells and damaged the normal cells. This part of the experiment confirmed the observations of Cornman. The highly purified penicillin salt, however, failed to inhibit the growth of sarcomatous and of normal cells. Dr. Lewis concludes that the factor present in the less purified sodium salt of penicillin is lost from the highly purified product.

#### TRANSCAPILLARY EXCHANGE OF SODIUM IN NORMAL AND SHOCKED DOGS

Previous annual reports of this Department, in Year Books No. 41 and No. 43, reviewed a series of studies by Dr. Louis B. Flexner and various collaborators on the transfer of substances across the placenta from mother to fetus, and from blood to tissues across the blood capillary walls of the body in general. The methods used in these important studies were applicable to one of the most serious of war problems, namely traumatic shock. Dr. Alfred Gellhorn, who was working with Dr. Flexner before our entrance into the war, undertook studies on the physiology of shock in our laboratory under a grant from the Committee on Medical Research of the Office of Scientific Research and Development. A summary of the work has now been published by Dr. Gellhorn, Dr. Margaret Merrell, of the Johns Hopkins Uni-

versity School of Hygiene, and Dr. Robert M. Rankin. These workers compared the rate of exchange of sodium chloride from blood to tissues in normal animals and in animals placed in a state of surgical traumatic shock under anesthesia. The movement of the salt was followed by using radioactive sodium chloride ( $\text{Na}^{24}\text{Cl}$ ) as explained in previous Year Books. The investigators ran into a certain amount of difficulty owing to the complications of the problem. Their work disclosed, for example, that the curve describing the rate of transfer of sodium chloride from blood vessels to tissues is complex and can only be understood by assuming that there are two rates at which the salt passes back and forth between plasma and extravascular fluids, presumably due to differences in different parts of the body.

After full mathematical analysis of the results it is shown that in shocked, untreated animals the total number of milligrams of sodium exchanged across the capillary walls per unit of time is about 50 per cent of the normal. When the animals are treated by replacement therapy with saline solution or serum, the defective rate of exchange is not improved, in spite of temporary better clinical appearance of the animals.

This finding, namely of a lessened transcapillary movement of sodium, is not easily reconciled with current theories of traumatic shock which postulate an increase of capillary permeability as fundamental to the diseased state.

#### DIFFUSION AND POPULARIZATION OF RESULTS

As already mentioned, the Director's Terry Lectures, given in March 1944 at Yale University, have appeared in book form under the title *Ourselves unborn*. In this volume, many of the problems in which this Department has been inter-

ested are reviewed for the educated general reader. Dr. Corner also published during the year, by request of the editor of *Parents' Magazine*, a journal issued under the auspices of several university groups, a popular article on human sterility from the

standpoint of the scientific investigator. Dr. Heuser, Dr. Burns, and Dr. Corner each lectured by invitation once or twice during the year to the students of Johns Hopkins Medical School.

A significant demonstration of the usefulness, outside our own walls, of our large collection of embryological materials is given by the latest textbook of human embryology, an excellent work by W. J. Hamilton, of St. Bartholomew's Hospital Medical College, London; J. D. Boyd, of the London Hospital Medical College; and H. W. Mossman, of the University of Wisconsin (*Human embryology*, Cambridge

[England], Heffer, 1945). Dr. Boyd and Dr. Mossman have been visiting investigators at the Department of Embryology in past years, and are therefore directly familiar with the resources of the Department. More than 90 of the 364 illustrations in the new textbook are drawn from the embryos of the Carnegie Collection or from articles by workers connected with the Department. It is a pleasure to note that Professors Hamilton, Boyd, and Mossman dedicate their book to Dr. George L. Streeter jointly with Professor T. H. Bryce, of Glasgow.

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## DEPARTMENT OF GENETICS

*Cold Spring Harbor, Long Island, New York*

M. DEMEREC, *Director*

During the war, because of the nature of our work, staff members of this Department were not called upon to participate in war research to any considerable extent. The Department carried out two war research contracts, one with the War Production Board and the other with the Office of Scientific Research and Development. In addition, several members participated in other research related to the war emergency. The objective of our work under WPB contract was the development of a strain of *Penicillium* yielding a high content of penicillin. This work was successfully carried on by E. Sansome, M. Demerec, and H. E. Warmke; and a high-yielding strain, now used in production, was selected from among mutants induced by X-ray treatment. The contract with OSRD, which is still in effect, deals with the genetic aspects of resistance in bacteria. For two years Warmke cooperated with the Bureau of Plant Industry of the U. S. Department of Agriculture in research aimed at the development of strains of fiber hemp with reduced marihuana content. He also participated in breeding studies on the rubber-producing Russian dandelion (*Taraxacum kok-saghyz*). Kauffmann, in collaboration with Dr. A. Hollaender, of the National Institute of Health, Bethesda, Maryland, investigated the effect of ultraviolet radiation on the mammalian eye, with the purpose of developing standards for prevention of industrial hazards. Demerec and Potter took part in research at the Biological Laboratory, under contract with the Chemical Warfare Service, relating to the production and properties of aerosols. For one phase

of this work, MacDowell supplied mice from his colony. Since 1943 Fano has been active at the Ballistic Research Laboratory, Aberdeen, Maryland, first on a part-time basis and later as a full-time worker. The Department cooperated with the Office of War Information by preparing for its Genetics News Letter monthly statements giving abstracts of important papers and brief summaries of other developments in the field of genetics.

Several members of the Department were taken into military service. In the Army Air Forces Dr. J. S. Potter served for a brief period as a captain, Louis R. Stillwell, Jr., and Robert Holl are serving as officers, and Dr. R. A. Miller is working as a corporal in a research laboratory.

In October 1944 Dr. Oscar Riddle retired from the Institution, but he remained with the Department until August of 1945 in order to complete his manuscripts. In September 1945 he became visiting professor of the Department of State in Brazil, Uruguay, and Argentina. Riddle came to the Department from the University of Chicago in 1912, as a Research Associate of the Institution. He brought with him the late Professor C. O. Whitman's pigeon material, and spent his first few years at Cold Spring Harbor in editing Whitman's work for posthumous publication. In 1914 Riddle was appointed a staff member of the Department. During his entire stay here he worked almost exclusively with pigeons and doves as experimental material; and his primary interest was in problems of sexuality, reproduction, and internal secretions. Although his approach was physiological, he was always aware of

genetical applications; and on many occasions he was able to trace physiological differences to differences in genetic constitution of the birds. When in 1932 he discovered a new hormone, prolactin, the emphasis on chemical aspects of his problems became greater. From that time on a chemist was included among the workers in his group; and this has had a significant effect on the work of the whole Department, broadening the general range of interest of the group. With Dr. Riddle's retirement the members of the Department have felt the loss not only of their oldest colleague, but also of a good friend and a sympathetic adviser.

Dr. H. E. Warmke left the Department in August 1945, to organize a Department of Plant Breeding at the Institute of Tropical Agriculture in Puerto Rico.

Much of the effort of Riddle and his associates during the year has been concentrated on analysis and summarization of data obtained in long-term investigations. The manuscript of a small volume on the subject of carbohydrate and fat metabolism in pigeons has been completed. The results of the twenty-four-year study on the relation of endocrines to constitution in doves and pigeons have been summarized in the more extensive forthcoming volume "Endocrines and constitution in doves and pigeons." McDonald and Riddle have finished their studies on the effect of reproduction and estrogen administration on the partition of the various calcium, phosphorus, and nitrogen components of pigeon plasma. The nonultrafiltrable calcium was found to exist in three forms: (a) colloidal calcium phosphate, (b) calcium bound to the phosphoprotein, serum vitellin, and (c) calcium bound to the plasma proteins other than vitellin. Increments in (a) and (b) accounted for all the increases in nonultrafiltrable calcium resulting from endog-

enous or administered estrogen. The calcium-combining capacity of the phosphoprotein, serum vitellin, is apparently 8 to 9 times greater than that of the other plasma proteins. All the changes in the various components that occur in the plasma of female pigeons at or near egg production can be duplicated by the injection of estrogens; and estrogens are effective in mature and immature, normal, parathyroidectomized, and hypophysectomized pigeons of both sexes. Thyroxine, when administered simultaneously with estrogen in equal amounts by weight, prevented the marked estrogen-induced increases in plasma calcium, phosphorus, and neutral fat. It did not measurably inhibit the ability of estrogen to promote formation of endosteal bone or growth of the oviduct. McDonald has continued her studies on the alcohol solubility of the plasma proteins. These have shown that serum albumin (and, to a lesser extent, some of the globulin fractions) is highly soluble, in the range of pH below its isoelectric point, in 95 per cent ethanol. Hollander and Riddle have noted the occasional onset of nongenetic partial melanism in adult female pigeons of essentially wild-type coloration. This partial melanism was associated with only slight exposure to sunlight and enlargement of the parathyroids. It appeared after one or more molts. The blackening, when it did not involve entire feathers, produced transverse bands on the feathers, not longitudinal streaks such as are typical of mosaic effects. Parathyroid enlargement and defective ossification of the bones were shown to occur regularly in young pigeons reared on a mixed-grain diet in the absence of direct sunlight (vitamin D deficiency). Melanism, however, was not found in these squabs.

MacDowell has found that the Cold Spring Harbor albino strain of mice (Balb) has a relatively high susceptibility

to spontaneous leukemia, although the resistance of this strain to all causes of death is so great, and the appearance of leukemia is so delayed, that this marked susceptibility was not recognized until a special study was recently completed. Dr. Gasic came to this laboratory as a Fellow of the John Simon Guggenheim Memorial Foundation from the University of Chile, Santiago, to test upon leukemic growth the efficacy of different steroid hormones, which had been found by Dr. A. Lipschütz, of the Chilean National Health Service, to have a striking influence on fibrous tumors in guinea pigs. Using a virulent line of transplanted mouse leukemia, Gasic found that death was delayed slightly (less than one day) in mice treated with pellets of testosterone propionate, but that desoxycorticosterone and progesterone had no effect on the time of death. Gasic has pointed out that many of the features of the alarm reaction of Selye are shown by mice dying with highly virulent transplanted leukemias. Bieseile has found that normal chromosome size varies with age in the rat. According to the tissue, there is an increase, a constancy, or a decrease. Similarly, in normal lymphatic tissue of C<sub>58</sub> mice there is an ontogenetic decrease in size of chromosomes, but in the transition to spontaneous leukemias and from them to long-transplanted leukemic lines there is an increase in size of chromosomes, which occurs gradually rather than by an abrupt doubling. Chromosome size in leukemic cells is influenced by the sex of the host and can be modified by means of male sex hormone.

Kaufmann has continued his analysis of the mechanism of chromosome breakage and recombination by treating spermatozoa of *Drosophila* with combinations either of X-rays and ultraviolet rays or of X-rays and near infrared rays. Ultraviolet radiation of wave length 2537 Å, when it

penetrates spermatozoa previously exposed to X-rays, effectively reduces the frequency (as compared with the controls) of chromosomal rearrangements that are detected by analysis of salivary-gland chromosomes. Near infrared radiation likewise, under certain conditions of treatment, will reduce the frequency of chromosomal rearrangement; but the effect is not directly on the regions of X-ray-induced breakage, as with the ultraviolet radiation, but on those processes that make spermatozoa that were not mature at the time of treatment available for transfer in copulation. When treatment with near infrared radiation precedes X-ray exposure, the chromosomes are effectively sensitized to breakage by the X-rays, as is indicated by the higher frequency of detectable rearrangement as compared with the controls. On the basis of the extensive data (about 3750 pairs of glands) collected in these and other studies, Kaufmann has re-examined the question of chromosome recombination, and now reports that, so far as the X chromosome of *Drosophila melanogaster* is concerned, the degree of randomness of recombination varies according to whether the breaks occur in euchromatin or in heterochromatin.

Demerec has developed a special technique for detecting in *Escherichia coli* mutants resistant to bacteriophages, which involves applying the phage to the culture in the form of a fine aerosol. With material treated with ultraviolet radiation of wave length 2513 Å, evidence was obtained that the increased mutation rate induced by irradiation persists over a considerable period of time, presumably through a number of cell divisions. Luria has detected two types of resistance to penicillin in *Staphylococcus*. In one type the bacteria are resistant because they secrete penicillinase; in the other type there is no evidence for an inactivator of penicil-

lin. Mrs. Witkin has found that difference in resistance to ultraviolet in *E. coli* is due mainly to a difference in the ability of bacteria to initiate division after irradiation. Demerec has devised a method for treating adult *Drosophila* with aqueous solutions of various chemicals by keeping the flies in an atmosphere containing an aerosol of the solution in question. Observations made by Dr. Jack Schultz, of the Lankenau Hospital Research Institute, on flies treated with aerosols of various dyes indicated that the material was present in the crop and digestive organs of the flies and, in some instances, in the testis.

Th. Dobzhansky, Research Associate of the Institution, has been investigating the rapid evolutionary changes discovered in natural populations of the fly *Drosophila pseudoobscura* in certain localities in California. These changes seem to be connected with the annual climatic cycle: some genetic variants become more frequent in the populations during the summer and other variants during the spring. The causative agent that operates here is natural selection; some variants are more favorable in spring and others in summer environments. This is interesting in itself, because very few well established instances of observable changes produced by natural selection are known. What makes the case of *Drosophila pseudoobscura* unique is that the changes observed in nature can be reproduced in part in the laboratory. For this purpose, artificial populations of flies of this species are set up in specially constructed "population cages," and samples of these populations are taken and examined from time to time. The most significant result to date is that in population cages kept at higher temperatures ( $25^{\circ}$  C., or summer room temperatures) changes are observed which coincide both in direction and in speed with those taking place in natural populations during the

summer. At lower temperatures ( $16^{\circ}$  C.) the composition of the populations in the population cages remains constant. This shows that the advantages or disadvantages that a genetic variation may produce in an organism are greatly dependent on even relatively small changes in the environment: at  $25^{\circ}$  C. some of the variants involved in these experiments are much superior to others in the struggle for survival, whereas at  $16^{\circ}$  C. all seem to be equally viable. Now, natural populations of at least some organisms are composed of mixtures of numerous genetic variants, with different environmental optima and different responses to changes that may occur in the milieu in which they live. This fact permits us to understand the remarkable adaptability shown by species of many organisms, within short intervals of time as well as in geological time, which is one of the most important phenomena of evolution.

Warmke has continued his investigations of polyploidy and sex in *Melandrium*. He has found that the spontaneous breakage of the Y chromosome observed previously is associated with bridge formation, particularly at the second meiotic division. By studying plants with various types of Y-chromosome deficiency, which arose from the spontaneous breakage, he has been able to resolve the process of male development into three separate steps: (1) the initiation of maleness, (2) the completion of maleness, and (3) the suppression of femaleness. The first of these processes is controlled by a gene or genes near the centromere of the Y chromosome, the second by a gene or genes near the top of the differential arm, and the last by a gene or genes near the end of the homologous arm. These steps appear to be qualitatively distinct from one another.

During the fall of 1944, McClintock spent a period of ten weeks at the Bio-

logical Laboratories of Stanford University and undertook a preliminary investigation of the chromosomes of *Neurospora*. Recent investigations with fungi have demonstrated their superiority as genetic materials, but little has been done to coordinate the genetic studies with studies of chromosomal conditions. If the full advantages of fungi as genetic materials are to be realized, a knowledge of chromosomal conditions and behavior is requisite. Many genetic investigations would be simplified and our understanding greatly enhanced if concomitant cytological analyses could be made. The brief study of the chromosomes and their behavior in *Neurospora* has suggested not only that some fungi are superior genetic materials, but also that they may be adequate and in some respects superior cytogenetic materials. The observations of *Neurospora* included determinations of chromosome number, absolute and relative sizes of chromosomes, centromere positions, internal organization of the chromosomes, zygote formation, and chromosome behavior in the two meiotic mitoses and the equational mitosis that follows, as well as scattered observations of several chromosomal translocations. Several phenomena of considerable theoretical interest were noted; in particular, the contracted state of the chromosomes at the time of synaptic association. On returning to Cold Spring Harbor, Dr. McClintock resumed her studies with maize. These studies are aimed at the production of mutations in a specific segment of the chromosomal complement. If our knowledge of the mutation processes is to advance, some methods should be devised for the induction of specific mutations, and some understanding should be obtained of the phenomena associated with the origin of these mutations. Previous investigations with maize have suggested a possible method.

The very special behavior in successive nuclear divisions of a recently broken end of a chromosome was utilized as the mutation-inducing agent. In these studies, the short arm of chromosome 9 was the particular segment of the chromosomal complement under investigation. Theoretical considerations had indicated that it should be possible to obtain a number of new mutations located at various positions throughout the full short arm of chromosome 9. To date, 69 mutations have been located in the short arm of chromosome 9, but they represent only 7 distinct types because of the repeated occurrence of the same mutations. New phenomena of chromosome behavior and new mutants with provocative phenotypic expressions have appeared as a part or an adjunct of these experiments.

Because of the increasing pressure of his duties at the Ballistic Research Laboratory, Fano could not continue to act as scientific adviser for the Survey of the Human Resources of the State of Connecticut. Therefore Dr. Ruby Jo Reeves Kennedy, of the Connecticut College for Women, New London, Connecticut, has taken his place as scientific adviser; Miss Mabel A. Matthews, Director of the Social Service Department of the Mansfield-Southbury Training Schools, is in charge of the project.

Dr. S. G. Stephens is spending a year with us as a Research Associate of the Department. Dr. Edgar Anderson, of Washington University, St. Louis, Missouri, and Dr. William L. Brown, of the Pioneer Hi-Bred Corn Company, Johnston, Iowa, spent about three weeks in June and July working with Dr. McClintock. A number of geneticists worked during the summer at the Biological Laboratory, in close contact with our Department. These included Max Delbrück, of Vanderbilt University; Myron Gordon, of

the New York Zoological Society; Ernst Mayr, of the American Museum of Natural History; Jack Schultz, of the Lan-

kenau Hospital Research Institute; and C. C. Tan, of the National University of Chekiang, China.

## CYTOGENETIC STUDIES OF MAIZE AND NEUROSPORA

BARBARA McCLINTOCK

### INDUCTION OF MUTATIONS IN THE SHORT ARM OF CHROMOSOME 9 IN MAIZE

In the past, many methods have been used to induce mutations. The majority of these methods do not give rise to specific mutations or to mutations confined to specific regions of the chromosome complement. Instead, a random assortment and distribution of mutations are obtained. A better understanding of the factors involved in the mutation processes would be possible if specific mutations associated with specific regions of the chromosomal complement could be effected. Recent investigations with maize have suggested several approaches to the problem of induction of specific mutations. One of these will be considered in this report. In previous reports, the repeated induction of the mutants *pyd* (pale-yellow seedling), *wd* (white seedling), and *yg* (yellow-green seedling and plant) has been described. Their origin has been associated with the behavior in several successive nuclear divisions of a recently broken end of a chromosome. This behavior has been called the chromatid type of breakage-fusion-bridge cycle. The *pyd* mutant appeared when the chromosomal complement was deficient for a small terminal segment of the short arm of chromosome 9; the *wd* mutant appeared when a slightly longer terminal segment was missing. The mutant phenotype *bz* (bronze) has likewise appeared following the production of a specific internal deficiency, as previously described. From this and other types of evidence, it has been concluded that specific mutations will arise as the conse-

quence of specific minute deficiencies. If the breakage-fusion-bridge cycle could give rise to a number of different internal minute deficiencies, and if the short arm of chromosome 9 were subjected to this process, various new mutants other than *pyd*, *wd*, *yg*, and *bz* should appear, each related to loss of a specific minute segment within this arm. The methods used to isolate the mutants *pyd*, *wd*, *yg*, and *bz* were selective. Therefore, a random sample of mutants which might be produced as the consequence of the breakage-fusion-bridge cycle did not appear. During the past year, nonselective methods have been used to determine whether the expected new mutants actually are being produced.

Cytological observations of the breakage-fusion-bridge cycle, as well as theoretical considerations, have indicated that this cycle will result in the production of internal deficiencies. Occasionally, a chromatid bridge in an anaphase figure is broken at more than one place. If a chromatid bridge breaks in three places, two centric chromosomes with a single broken end and two acentric fragments, each with both ends broken, will be formed. It is possible for the two fragments to enter one telophase nucleus along with the centric chromosome. If, in this nucleus, a particular type of fusion of broken ends occurs, a centric rod chromosome with an internal deficiency and an acentric ring fragment can be produced (following fusion of the two broken ends of the proximal fragment to form an acentric ring, and fusion of one broken end of the distal fragment with the broken

end of the centric chromosome). If the remaining free broken end of the centric rod chromosome healed and no longer underwent the breakage-fusion-bridge cycle, a chromosome with an internal deficiency might subsequently be isolated. Sufficient cytological evidence has accumulated to support the assumption that this is one method of origin of internal deficiencies. Theoretical considerations suggest a second method for obtaining internal deficiencies. Many investigators have considered the anaphase chromosomes to be multiple, that is, composed of two or more sister strands. It is probable that effective doubleness at anaphase is present in some cells or tissues and not in others. Should a chromatid bridge at anaphase be composed of two sister strands, breakage need not occur at comparable positions in the two strands. Should the breakage be unequal, the chromatin composition of the two sister strands entering a nucleus would not be comparable. They could differ by various duplications or deficiencies. If, in the following telophase, fusion occurred between the two broken ends of the unequal strands, the chromatin components between the two centromeres would consist of two dissimilar instead of similar segments. A chromatid bridge and breakage of this bridge would follow in the next mitotic division. Should the resulting newly broken end heal permanently, it might be possible subsequently to isolate a chromatid with an internal deficiency. The type and extent of deficiency would depend on the positions of breakage in these two divisions. This process would give rise to internal deficiencies without fragment formation. Again, theoretical considerations have suggested that the *chromosome* type of breakage-fusion-bridge cycle (see previous reports) should result in chromosomes with internal deficiencies

ranging from minute to extensive. Therefore, both the chromatid and the chromosome type of breakage cycle have been utilized in an attempt to produce and isolate new mutations confined within the short arm of chromosome 9.

To isolate new mutants produced by the *chromatid* bridge cycle,  $F_2$  progeny derived from  $F_1$  plants that had received a recently broken chromosome 9 from one parent were examined. To isolate new mutants produced by the *chromosome* bridge cycle, the selfed progeny of individuals that had received a newly broken chromosome 9 from each parent were examined. In many cases, the constitution of the short arm of the chromosomes 9 with healed broken ends had been considerably altered during the period of the breakage cycles. Large as well as small duplications or deficiencies frequently were present. Many of these altered chromosomes 9 did not pass through the gametes to the next generation. Whenever the pollen grains and eggs carrying the chromosomes 9 with altered short arms were capable of effecting fertilization, the selfed progeny could include individuals homozygous for these altered short arms. Should an alteration, when homozygous, result in a changed phenotype, individuals with a distinct mutant character would appear in the progeny. Considerations of space and labor confined the search for new mutations mainly to the kernels and the seedlings. A number of new mutants appeared in these progenies. The most clearly defined of these mutants were selected to determine whether or not they were located in the short arm of chromosome 9. Only 3 of the distinctly new types of mutant have been sufficiently analyzed to indicate their positions in the short arm. These are a small-kernel mutant (*smk*), a spotted-leaf mutant (*spl*), and a pale-green mutant (*pg*). The *smk* and *spl* mutants

are located in the distal third of the short arm, whereas *pg* is located between the mutants *sh* and *wx*. Many new *pyd* and *wd* mutants and a few new *yg* mutants appeared in these cultures. Although 69 mutants arising from newly broken chromosomes 9 have been tested, they represent only 7 distinct phenotypes because of the repeated occurrence of the same mutations. In the published linkage group of chromosome 9, 7 spontaneously arising mutants have been placed in the short arm. The symbols for these are: *Dt*, *yg*, *C*, *sh*, *bz*, *bp*, and *wx*. The newly broken chromosomes 9 have given the 7 mutants *pyd*, *wd*, *yg*, *smk*, *spl*, *bz*, and *pg*. As has been stated previously, the *yg* and *bz* mutants derived from the broken chromosomes 9 are allelic to the 2 mutants, *yg* and *bz*, that arose spontaneously in genetic cultures.

An interesting type of chromosomal behavior has appeared in three of the broken-chromosome cultures mentioned above. In each culture, one of the broken chromosomes 9 is continually being lost from cells during development. This loss is not due to bridge formation or to ring chromosome behavior, but appears to be caused by the inability of the two halves of this chromosome to migrate to opposite poles in some of the somatic anaphase figures. The rate of loss varies widely from plant to plant. Within a single plant, changes in rate occur; this is made evident by the presence of distinct sectors each with its own rate of loss. To date, only a cursory examination of the nature of this phenomenon has been made; it warrants further study. In addition, some of the mutants appearing in these cultures are individually provocative. Several show variegation characterized by a change from mutant to normal-appearing tissues. For any one plant, a distinctive or basic rate of change is apparent, but this basic rate differs from plant to plant. Sectors with changed rates

of variegation appear in all plants, especially in the later-appearing tissues. It is significant that twin sectors accompany many if not most of the alterations in rate; this is expressed by the appearance of a sector of tissue having a greatly increased rate of variegation immediately adjacent to a sector of tissue having a much reduced rate of variegation.

#### PRELIMINARY STUDIES OF THE CHROMOSOMES OF THE FUNGUS *NEUROSPORA CRASSA*

During the fall of 1944, a period of ten weeks was spent in the Biological Laboratories of Stanford University, where genetic studies are being conducted with the fungus *Neurospora*. The purpose of this visit was to obtain some knowledge of chromosomal and nuclear behavior in *Neurospora crassa*. Although fungi have assumed an important role as genetic materials, little has been done to coordinate the genetic studies with a study of chromosomal conditions. As genetic investigations with fungi progress, the necessity for correlative cytogenetic analyses will become increasingly evident. It was a pleasure to have the opportunity of examining *Neurospora* in this laboratory. Progress was greatly accelerated by the availability of large numbers of stocks, both wild-type and mutant, and by the generous and cooperative support of the members of the department.

The observations were confined to the chromosomes and nuclei of the ascus. They included observations of chromosome numbers, absolute and relative sizes of the chromosomes, centromere positions, internal organization of the chromosomes, zygote formation, chromosome behavior in the two meiotic mitoses and the equational mitosis which follows, and scattered observations of several chromosomal translocations. In the short time available, no

one of these topics could be adequately considered. Nevertheless, this over-all survey has suggested that some fungi may be adequate and, in several respects, superior material for cytogenetic studies.

The haploid number of chromosomes in *Neurospora crassa* is 7. Each chromosome of the complement is distinguished by its relative length, the position of its centromere, and its internal organization. The longest chromosome is approximately 2.7 times as long as the shortest. The second-longest chromosome, chromosome 2, has a nucleolus organizer located close to the end of the short arm. The organizer region functions to produce a nucleolus in a manner similar to that observed in many other organisms. Because of its location close to the end of one arm of this chromosome, a minute satellite is formed. Throughout the various nuclear cycles, the relative lengths of the chromosomes of the complement are maintained. Therefore, absolute lengths need be given only for the longest chromosome. In the third division in the ascus, which is equational, this chromosome may be only 1.5 microns long. At the full meiotic prophase extension, it may be 15 microns long. Chromomere patterns were observed at this latter stage; each chromosome appears to have its characteristic pattern. Centromere positions were adequately determined for the two longest chromosomes, and approximate positions were obtained for the other five chromosomes. Two heterochromatic segments were observed and located adjacent to the centromere, but the chromosome or chromosomes carrying these heterochromatic segments were not identified.

Fusion of two haploid nuclei to form the zygote nucleus occurs in the very young ascus. The two sets of chromosomes in this zygote nucleus then commence the activities associated with meiosis. The behavior of the chromosomes in the

early meiotic stages is of considerable theoretical interest. During meiosis in most organisms, homologous associations commence when the chromosomes are in a very elongated state. In the *Neurospora* strains most intensively studied, this occurs when the chromosomes are greatly contracted. Following nuclear fusion, the chromosomes contributed by each nucleus undergo what appears to be a typical prophase contraction without visible evidence of splitting, until, in some strains, the chromosomes are almost as short as those of the metaphase of the third division in the ascus. In this highly contracted state, the homologous chromosomes commence their synaptic associations. Before the chromosomes have reached this state, fusion of the nucleoli contributed by the two nuclei usually has occurred. Actual physical association of the homologues usually begins at one or both ends and continues along the chromosomes. In many nuclei, synapsis is completed for some pairs of chromosomes before the members of the other pairs have approached sufficiently close to each other to commence actual contacts. It is not clear from these studies whether the approach of homologous chromosomes toward each other is directed or whether it follows from random movements of the chromosomes in the nucleus. It is of considerable theoretical interest to determine the range of the synaptic force which brings about homologous associations of chromosomes. It is suspected that the young asci of *Neurospora* might be readily cultured. Because of the relatively large volume of the nucleus and the small size of the chromosomes in these asci, continuous observations of the behavior of these chromosomes in the living nuclei might be possible.

Following the synaptic phase, the associated homologous chromosomes begin to elongate until, as stated above, the longest

chromosome may reach a length of 15 microns. Diplotene sets in rather suddenly following the completion of elongation of the synapsed chromosomes. The period from diplotene to metaphase I is passed through very rapidly. At diakinesis, typical chiasmata may be observed leading to rather orthodox, even though small, metaphase I bivalents. Although the nucleolus becomes smaller during the prometaphase stage, it is still present at metaphase. Chromosome 2 remains attached to the nucleolus by its organizer region. Anaphase I appears to be essentially typical except for the presence of the nucleolus. The nucleolus may be dragged toward one pole or stretched between the poles because the nucleolus organizer of one or more chromatids of chromosome 2 still remains attached to it. The nucleolus becomes detached before telophase sets in. At telophase I, and likewise at telophases II and III, the centromere regions of all the chromosomes form an aggregate that lies at the apex of a distinct protrusion of the nucleus (the beak). No true resting nucleus is formed. Instead, the chromosomes uncoil, the individual arms of each chromosome extending into an elongated nucleus. A new nucleolus is formed and remains attached to the nucleolus organizers of chromosome 2. Contraction of the chromosomes initiates prophase II. This continues until the two dyad chromosomes are in the form of short, parallel rods, each showing a conspicuous centromere region. Metaphase and anaphase II are essentially typical. At telophase II the centromere regions are again aggregated at the apex of the beak of the nucleus; the chromosomes uncoil and the two arms of each

chromosome extend into the nucleus as individual strands. They remain in this condition until the following prophase. The extent of elongation of the chromosomes appears to be similar to that observed in the meiotic prophase. In each nucleus, a new nucleolus is formed at the position of the nucleolus organizers of chromosome 2. Prophase III is initiated by contraction of the arms of the chromosomes. The metaphase and anaphase of division III proceed as a typical equational mitosis. The resting stage of nuclear organization follows telophase III. Shortly after spore delimitation, a mitosis occurs in each ascus. This is also a typical equational mitosis. In essential details, divisions I and II are typically meiotic. Division III is essentially a somatic mitosis, except that the chromosomes retain their identity as elongated strands from the telophase of division II to the prophase of division III. The time of effective splitting of the chromosomes for this division is of some theoretical interest.

Because many of the mutations in *Neurospora* have appeared following X-ray and ultraviolet irradiation, it was suspected that various types of chromosomal translocation might likewise have been induced by these treatments. Three irradiation-induced mutants, whose genetic behavior suggested the presence of some chromosomal abnormality, were selected for examination. A translocation between two nonhomologous chromosomes was found in each case. Intensive studies of these translocations were not undertaken, but the preliminary observations have suggested the usefulness of some translocations for attacking special problems.

## POLYPLOIDY INVESTIGATIONS

H. E. WARMKE, HARRIET DAVIDSON, AND GERMAINE LECLERC

The work of this laboratory during the past year has been largely devoted to a study of spontaneous breakage of the Y chromosome in *Melandrium* and to an investigation of the number, position, and mode of action of the male genes made available for study by such breakage. The beginnings of these studies were mentioned last year, at which time certain contradictory observations were noted. Now these apparent contradictions have been resolved, and the essential facts stand out clearly.

These studies had their inception with the discovery that the chief male-determining genes in *Melandrium* are located in a single chromosome, the Y. This knowledge, and the development of inbred plants of the constitution 2A XXY, made possible an analysis of maleness in *Melandrium* similar to the analysis of femaleness made by Dobzhansky and Schultz, Pipkin, and others in *Drosophila*; that is, a determination of whether sex is controlled by a single or by many male-determining genes, and something of the location of this gene or genes in the Y chromosome. No similar investigation of maleness has been made previously, on either plant or animal material, so far as we are aware.

#### BREAKAGE OF THE Y CHROMOSOME IN 2A XXY PLANTS

Cytological examination of plants with broken Y chromosomes shows that fragments are constant in size in all parts of a given plant. This evidence, together with the absence of sectorial chimeras, indicates that the breakage does not occur somatically, but is a meiotic phenomenon. This inference was borne out by the discovery of meiotic bridges, involving the Y chromosome, apparently in sufficient

numbers to account for the observed incidence of breaks.

These bridges, however, are not of the usual type, which results from crossing over in heterozygous inversions. The bridges observed in 2A XXY individuals of *Melandrium* appear to be restricted largely to the second division, and are not accompanied by acentric fragments. Though the exact cause of bridge formation is not clear, it appears to be associated with asynapsis of the Y chromosome. There is a close correlation between the amount of asynapsis and of bridge formation, and the number of broken Y chromosomes recovered.

When the Y chromosome fails to synapse with either of the X's, it behaves as a univalent at meiosis. If it is not on the spindle at the first division, and is by itself, it may form a separate micronucleus; or, if it happens to lie near one of the poles, it may become incorporated in one of the daughter nuclei. In this latter case it splits longitudinally at the second division, and the two chromatids separate normally. If, however, the asynaptic Y comes to lie on the first-division spindle, it divides somewhat later than the other chromosomes but nevertheless one whole division cycle ahead of normal. The sister halves of such a precociously dividing Y chromosome may become incorporated in the telophase nuclei of the first division; or they may not have separated in time to be so included, and in this case they form small accessory nuclei. In either event they behave abnormally at the second division. Having already divided at the first division, they do not divide again at the second; instead they become laggards, are not under the control of their centromeres, and are variously distributed on the

spindle during the second division. These laggards, when caught by the spindle forces, are stretched and, it is believed, form the bridges which break and give rise to the observed Y fragments.

#### NUMBER, LOCATION, AND MODE OF ACTION OF MALE-DETERMINING GENES

As the result of selfing 2A XXY plants, the normal offspring—2A XXY (male-hermaphrodite), 2A XX (female), 2A XY (male), and 2A XYY (supermale)—are obtained, and in addition two abnormal hermaphrodite types appear. These are: (1) a type in which the female structures are highly developed, essentially as well developed as in 2A XX females and with normal stamens; and (2) the type described last year, in which there is a complete failure of stamen development shortly after meiosis. These segregants are easily distinguished from the normal types, and cytological examination has shown them to be associated with breaks in the Y chromosome. The first type occurs when the homologous (synaptic) arm of the Y is deficient. Deficiencies may range in size from a short terminal loss to one which appears to include the entire or nearly the entire homologous arm. It is interesting that the degree of abnormality is not proportional to the length of the deficiency; once a small terminal segment is lost, this phenotype appears, and larger losses do not cause more pronounced effects. One can be certain in such cases that the homologous arm, and not the differential arm, is the deficient one, by the fact that deficiencies in the homologous arm cause complete asynapsis of the Y chromosome. The asynaptic Y, as noted above, behaves as a univalent and is obvious in all figures. The segment that pairs with the X thus appears to be terminal and quite short; losses of as little as one-fourth or one-fifth of the arm prevent synapsis.

The second abnormal type of segregant, in which male development is arrested short of completion, with resultant male sterility, appears when there is breakage of the differential arm of the Y chromosome, or combined differential and homologous breakage. As with deficiencies in the homologous arm, a small terminal loss in the differential arm is sufficient to evoke the effect, and larger deficiencies do not increase this effect. Plants that have lost as little as one-fourth of the differential arm are male sterile and indistinguishable from plants that have lost most of both arms. The Y, in extreme cases of this latter type, may be represented at meiosis by only a small spherical fragment, smaller in diameter than the normal width of a chromosome, and in somatic mitosis by a fragment shorter than the smallest autosome. These fragments, down to the smallest, retain their centromeres and are carried through the mitotic growth divisions to every cell of the plant; only in rare cases and with the very smallest fragments is there evidence that somatic loss may occur.

The above observations are interpreted as indicating that maleness in *Melandrium* is not controlled by a single gene, or by an extremely large number (as is the case with femaleness in *Drosophila*). Specifically, there appear to be at least three genes or gene complexes in *Melandrium* that operate in the development of maleness, and more may well appear as more deficiencies are discovered. First, there is one near the centromere, and present in the smallest observed fragments of the Y chromosome, which *initiates male development*. Plants which lack this proximal part of the Y, as when it is lost somatically or is not originally present (2A XX types), are normal females; when this proximal segment is present stamens do develop, but just past meiosis. Second, there is a gene (or group of associated genes) near the

end of the differential arm of the Y that *completes male development*. When the entire differential arm is present full male development results, but when as little as one-fifth of the arm is absent in terminal deficiencies, male development stops where the male-initiating influence left off. Third, there appears to be a gene or region in the terminal fourth of the homologous arm of the Y which *suppresses femaleness*. Whether this is in the pairing segment or not is uncertain. When the entire Y chromosome is present (in addition to two X chromosomes), female structures are poorly developed; in only a small percentage of the blossoms are ovaries sufficiently well developed to set capsules with seed. When the homologous arm is deficient—that is, when this particular region is removed—female development is complete, and every blossom produces seed-filled capsules. Thus experimental evidence indicates that this part of the Y chromosome acts when present as a positive suppressor of the female-determining regions in the X chromosomes.

Basically it is important to know whether the genes controlling these three steps in male development are qualitatively different and control different reaction systems, or are only quantitative stages in a common over-all process. At least a

partial answer to this question is now possible, because of evidence obtained from two newly derived types of plants. These are plants with two sets of autosomes, two X chromosomes, and two deficient Y chromosomes.

One of these types had two Y fragments comprising the proximal region (the region necessary for the initiation of male structures), but none for male completion or female suppression. These two Y fragments, though unquestionably exceeding a complete Y in total amount of chromatin, did not combine to produce complete maleness. These plants were phenotypically indistinguishable from plants with only a single proximal Y fragment; they were male sterile because of incomplete male development.

A second and somewhat similar type has recently been synthesized; it has two Y fragments, each lacking the distal part of the homologous arm, that is, the female-suppressing region. These plants, though having two male-initiating segments and two male-completing segments, still are not able to suppress femaleness. It would thus appear that the genes governing these three essential steps in male development are qualitatively distinct from one another in their action and cannot be substituted one for another in a quantitative fashion.

## THE GENE

M. DEMERE AND S. E. LURIA

### ULTRAVIOLET IRRADIATION AND MUTATIONS IN *ESCHERICHIA*

Experiments with ultraviolet and X-rays were undertaken as a part of the program for studying the origin of bacterial resistance to various agents (Year Book No. 43). In experiments conducted by M. Demerec in collaboration with Miss M. Crippen and Miss N. McCormick, strain Br of *Escherichia coli* was treated with ultraviolet radiation of wave length 2513 Å,

and the rate of mutation from B to B/1—that is, to resistance to bacteriophage T1—was observed.

Bacteria were plated on Petri dishes and incubated. The controls begin to divide after about 50 minutes, and the bacteria treated with ultraviolet radiation after about 2 hours. Once they start to divide, the division periods are regular, one every 20 minutes. Therefore, if the number of bacteria put on each plate is known, the

number at subsequent periods can easily be estimated. Phage sprayed as an aerosol does not disturb the position of bacteria on a plate. It will eliminate all sensitive individuals, and the resistant ones will remain to form colonies. The number of mutations that has occurred during a certain interval can readily be determined by finding the number of resistant colonies at the beginning and at the end of the interval. The advantage of this method of applying phage is that the positions of bacteria are not changed. If mutation occurs early in the interval, a mutant bacterium will divide and produce several resistant bacteria, but all of them will be close together and will form only one colony.

In one set of experiments, the control series showed a mutation rate of about 1 to  $2 \times 10^{-8}$ , which is similar to that observed previously in untreated material. In a series treated with a dosage which kills about 98 per cent of bacteria, the mutation rate among bacteria immediately following treatment was about  $2 \times 10^{-6}$ ; among bacteria developing during the first 2 hours of incubation (one cell generation after treatment), the rate was about  $4 \times 10^{-6}$ ; among those developing during the interval between 2 and 3 hours (2d and 3d cell generation) after treatment, it was about  $2 \times 10^{-6}$ ; and among those developing during the interval between 3 and 4 hours (4th to 6th generation) after treatment, it was about  $3 \times 10^{-6}$ . Results of another series of experiments indicated that the mutation rate reaches its normal level after the bacteria have passed through ten to twelve divisions.

These data show that the increased mutation rate induced by ultraviolet irradiation persists over a considerable period of time, presumably through a number of cell divisions. Experiments are now under way to trace down the reasons for this persisting effect.

#### BACTERIAL RESISTANCE

Last year's report (Year Book No. 43, pp. 109-110) contained a summary of work on the genetic aspects of the origin of resistance to penicillin of *Staphylococcus* bacteria. Results of that work indicate that resistant bacteria occur as mutants independently of the action of penicillin, that resistance develops in steps, and that the progress of the building up of resistance is more rapid with each step.

In June 1945, an extensive research project was started, dealing with the genetics of acquired bacterial resistance to drugs and other antibacterial agents. Dr. S. E. Luria, who is on leave of absence from Indiana University, is taking a leading part in this research. In July and August he was joined by Dr. E. Oakberg, Mrs. E. Oakberg, Miss R. Arbogast, and Mrs. E. Witkin.

The scope of this project is twofold. Its aims are, on the one hand, to solve practical problems arising from bacterial resistance to therapeutic agents, and, on the other hand, to obtain fundamental knowledge about bacterial genetics—in particular, about the mutational patterns of bacteria and the underlying physiological mechanisms. The present approach to this problem is based on the analysis of the distribution of mutant individuals in uniparental populations made by Luria and Delbrück in 1943. This analysis has been applied successfully to the study of bacterial resistance to bacteriophages (Luria and Delbrück, 1943; Demerec and Fano, 1944) and to penicillin (Demerec, 1945).

The present project includes work on resistance to penicillin, sulfonamides, inorganic salts, bacteriophages, and ultraviolet radiation. The work on penicillin resistance is directed toward clarification of several complex aspects of this phenomenon. Two types of penicillin resistance can

occur. In the first type the cells acquire, by mutation, tolerance to higher concentrations of the antibiotic, without other evident physiological changes, as described by Demerec. In the second type the organisms secrete an inactivator of penicillin (penicillinase), which protects them from penicillin although they are individually sensitive. The genetic basis of this second type of resistance is still obscure. In the course of the work, a rapid quantitative test for penicillin resistance in staphylococci has been devised for use in medical laboratories.

The problem of acquired resistance to sulfonamides has met with several difficulties because of the peculiarities of the phenomenon of bacteriostasis; in particular, because of its complex dependence on the initial number of bacterial cells present in a culture. This and other aspects of the problem are being methodically investigated.

Work on bacteriophage resistance is being continued with an analysis of complex mutations involving unusual changes in the resistance pattern of bacteria. Study of these mutations is being extended to an analysis of the correlated changes in growth-factor requirements. It is also planned to attempt investigation of the cytological aspects of the problem by nuclear stainings.

The occurrence of bacterial resistance to ultraviolet radiation, discovered by Mrs. Witkin last year (Year Book No. 43, pp. 110-111), is being further investigated. Resistance seems to be due mainly to a difference in the ability of bacteria to initiate division after irradiation. Improved techniques have been developed for an analysis of this type of resistance, and for investigation of the possibility that mutations to ultraviolet resistance, besides occurring spontaneously, are also induced by the radiation itself.

#### DEVELOPMENT OF A HIGH-YIELDING STRAIN OF *PENICILLIUM*

Beginning in September 1943, Mrs. San-some and M. Demerec, in collaboration with Dr. A. Hollaender, of the National Institute of Health, Bethesda, Maryland, started experiments to produce, by means of X-ray and ultraviolet irradiations, strains of *Penicillium* that would give high yields of penicillin. Experiments were conducted on a small scale until May 1944, when a contract with the War Production Board became effective and funds were made available for additional equipment and special assistants to carry on routine tests. At that time Dr. H. E. Warmke joined the group. The work was continued at the Department until November 1944. Since early in 1944, similar work, also under contract with the War Production Board, had been going on at the laboratories of Stanford University, the University of Minnesota, and the University of Wisconsin.

Penicillin may be obtained from a culture medium when *Penicillium* is grown on its surface, or when it is submerged and aerated by shaking or by bubbling air through the medium. At the time we joined the project it was known that high surface yielders may not be high yielders in submerged cultures, and vice versa. Manufacturing experience had indicated also that submerged culturing is more efficient and economical than surface culturing. Therefore, the aim of the project was to develop high-yielding strains with submerged culturing. Since a considerable amount of equipment is necessary for complete tests of the yielding capacity of submerged strains, it was decided to divide the work so that the irradiation and the preliminary rough screening tests to isolate possible high yielders would be carried out at our laboratory; further tests for

yielding capacity would be made at the University of Minnesota laboratory, where large shaking machines were already available; and the final tests would be carried on at the University of Wisconsin in 8-gallon tanks.

For efficient planning of experiments, it was essential to acquire certain fundamental knowledge about the reaction of *Penicillium* to X-rays. It is known that the frequency of mutations is proportional to the dosage, and also that the rate of killing of the treated spores increases with the dosage. The most efficient dosage for our experiments, therefore, was that which would produce a sufficiently high frequency of mutations and at the same time leave enough survivors.

In order to establish this dosage, the mutation rate and killing rate were determined on spores treated with 25,000, 50,000, 75,000, and 100,000 r-units. Spores were treated both dry and in saline suspension. Detailed results of these experiments are published in last year's report (Year Book No. 43, p. 113). On the basis of these results, a dosage of 75,000 r-units was selected for our experiments.

Tests were also conducted to find out whether the mutation rate or the germination rate of treated spores deteriorates when they are stored in a refrigerator. Since it was found that deterioration does not occur, it was possible to treat large batches of spores and to store them for subsequent use.

The majority of cultures obtained by irradiation of a high-yielding strain may be expected to have the same high-yielding capacity as the original strain. Consequently, the quick assay methods designed to screen out low yielders are not applicable to these cultures. What is needed is a quick assay method which will pick out the exceptional high yielders. In a search for such a quick screening method it was

thought worth while to investigate the possibility that the pellets formed in shaker flasks originate from single spores, in which case the penicillin-producing capacity of single pellets could be tested directly. An experiment designed to test this possibility revealed that pellets are formed from a mixture of mycelia originating from several spores.

After experimentation with various techniques, a standard procedure for making tests was developed. Spores of *Penicillium chrysogenum* were X-rayed on agar slants with 75,000 r-units. The irradiation was given by Mr. L. D. Marinelli at the Memorial Hospital in New York, at an intensity of 2420 r per minute. Treated spores were spread on the surface of potato-dextrose-agar plates; and immediately after germination they were isolated into test tubes containing 2 cc. of liquid culture medium. These were put into the shaker machine, which had a 4-inch horizontal stroke and operated at 250 strokes per minute. The tubes we used had an inside diameter of 10 mm. and were 110 mm. long. The size of tubes and the amount of nutrient in each tube is determined by the properties of the shaker. After 5 days of continuous shaking, a sample of the medium taken from each tube was diluted 100 times and assayed for penicillin content by the cup method, using *Staphylococcus aureus* (NRRL strain B313). Tubes showing a high yield were saved and the fungus growing in them was cultured; the remaining tubes were discarded. In this way about 90 per cent of the cultures were eliminated as low or average yielders, and 10 per cent were saved as possible high yielders and were shipped to the Division of Plant Pathology, University of Minnesota, St. Paul, for further tests. All together, 504 selected strains were sent to Minnesota. One among these was the strain now known as X-1612, which yields

about twice as much penicillin as the strain 1951.B25 from which it originated. This new high-yielding strain is now used in production of penicillin.

#### AEROSOL METHOD FOR CHEMICAL TREATMENT OF DROSOPHILA MELANOGASTER

In the course of extensive studies dealing with the induction of mutations in *Drosophila* by means of X-radiation, efficient methods have been developed for detecting induced as well as spontaneously occurring mutations. Dr. H. J. Muller developed the most useful one, which is designed to detect lethal mutations occurring in the sperm of male flies. The great advantage of this method is that one treatment reaches a large number of mature sperms, which may easily be tested for induced changes.

For many reasons it would be desirable to have a similar method for use in studies that attempt to induce mutations by means of various chemicals; specifically, a method whereby the male gonads could be reached without excessive injury to the flies and without its being necessary for the chemicals to pass through the digestive organs, where they might undergo change.

It has been shown by Auerbach and Robson (Nature, vol. 150, p. 80, 1944) that mutations may be induced in *Drosophila* sperm by exposing males to mustard oil vapor. It appears likely that the vapor enters the gonads through the numerous tracheae present in these organs. Now, if genetic changes in the sperm may be induced by materials entering the gonads through the tracheae, then it might be possible to affect sperm by using an aqueous solution of any chemical, in the form of an aerosol consisting of very fine droplets. With the aid of experience obtained during the past three years in a problem investigated at the Biological Laboratory, ap-

paratus was devised for exposing flies to aerosols having droplets less than 1.5 microns in diameter.

During the summer of 1945, M. Demerec, in cooperation with Wilton E. Baty, of the staff of the Huntington High School, and Zlata Demerec, carried on extensive experiments with aqueous aerosols of thirty chemicals, including oxidizing, reducing, and wetting agents and stains. In some cases brief exposure to an aerosol killed the flies, and in other cases the flies were not injured by long exposure. Experiments are now under way to determine whether or not genetic changes were produced in the sperm of treated males.

The utility of aerosols in attempts to alter the genetic constitution of *Drosophila* by chemical means depends on their mode of entry and the disposal of the substances in the fly. If aerosols enter as gases do, through the tracheae, the chemicals contained in them have almost immediate access to the heavily tracheated gonads; if not, they may be subject to the various methods of detoxification provided by the other portals of entry (alimentary, body surface). Accordingly, it seemed advisable to observe the fate of a group of dyes, whose presence in the different organs of flies exposed to aerosols made with these dyes could easily be detected on dissection. By using dyes known to be intravital stains, the penetration into the cells could be studied. Dr. Jack Schultz, of the Lankenau Hospital Research Institute, Philadelphia, who was working at the Biological Laboratory, participated in these studies and made most of the microscopic observations.

The dyes used were the familiar toluidine blue, neutral red, janus green, trypan blue, among the vital stains. In addition, tests were made with acriflavin, because of its known effects on amphibian sperm; with

the chromatin stains crystal violet, methyl green, and safranin O; and with the cytoplasmic and chromosomal counterstain fast green. Adult wild-type flies were subjected to aerosols containing maximal concentrations of these dyes, and observed for various periods following the beginning of treatment. The atmosphere of the culture bottle was renewed every half-hour, so that concentration of the aerosol was maintained at an approximately constant level.

These experiments, then, gave a picture of the course of entry of the dyes. Almost invariably, the first region to show the dye was the crop. Later, in the case of toluidine blue, neutral red, and acriflavin, the stain was visible in the cells of the midgut, with characteristic differences in detail. The staining was not uniform in all cells of the gut, but bands of cells at intervals were affected, indicating either a rhythm in the release of the material from the crop, or the existence of periodicities in the receptivity of the cells to the dye. At later stages, these dyes were observed in the Malpighian tubules and—most interesting—in the pigment granules of the testis sheath and in cysts of spermatogonia (*moribund?*). With other stains no absorption was evident; the dye was simply passed along the lumen of the gut for excretion. The final picture in all treatments was one of excretion of masses of pigment from the lumen of the hindgut.

It appears, then, that intake occurs via the proboscis and the alimentary tract. Indeed, the proboscis itself was often seen to be colored by the dye. Tests were made to determine the intake when the flies were prevented from feeding on the surface of the culture bottles. Following a suggestion of Dietrich Bodenstein, flies were mounted, according to the technique developed by Chadwick for studying the frequency of wing beat, by an attachment to the dorsal surface of the abdomen which

left the fly suspended in air with its legs and wings freely movable. Under these circumstances staining was similar to that observed in unmounted controls, although less intense. A few trials were made with flies mounted in the way described but with their front legs cut off to minimize the amount of dye obtained by licking from the surface of the body. The intake was further decreased, but still observable. The impression is therefore strong that chemicals are taken in by feeding on the film at any exposed surface, and also by swallowing aerosol.

The use of mutants that cannot fly provided evidence from a converse set of conditions. Crawling on the surface of the vessel, the mutant *vestigial* took in as much dye as the wild-type, or possibly more. A similar picture is presented by the mutant *Dichaete*, in which an alteration of the wing musculature extends the wings at right angles to the body. One additional point of interest appeared in the experiments with *Dichaete*: with toluidine blue, the crop rarely became inflated, the dye appearing only in the crop duct. This was not the case with other dyes—for example, neutral red—and constitutes an interesting problem on the physiology of the crop.

Whether there are other modes of ingress than by the alimentary tract was tested by the use of the mutant *proboscipedia*. In this mutant, Dobzhansky and Bridges showed, the proboscis is transformed into a leglike structure, with the opening to the buccal cavity completely overgrown in the extreme cases. As might be expected from the foregoing, those flies with closed proboscises showed no intake into the gut. They did, however, after being exposed for some time, show some concentration of dye near the tracheal endings around the ovary, for example; pigment could also be seen in the Malpighian

tubules. Since previous treatments had shown that aerosols of mercuric chloride kill wild-type flies, the lethal effect of this aerosol on proboscipedia was tested. The mutant flies were susceptible to approximately the same degree as the wild-type, indicating that penetration of the mercuric salt into the gut is not required for the lethal effect. It would seem, therefore, that in proboscipedia, and hence probably also in wild-type, there is some intake, of certain aerosols at least, through either the tracheae or the thinner parts of the body surface.

The occurrence of stained regions in the testis is, of course, of major interest. An attempt was made to study these more closely by the use of the white-eyed mutant, which lacks pigment in the testis

sheath and Malpighian tubules; because in flies where pigment granules are present they absorb the dye selectively. In the white-eyed flies, the dye was eliminated from the cells more rapidly, when it was absorbed at all, and became evident as a diffused staining of the cytoplasm. No obvious changes in the frequency or location of stained areas in the testis were seen.

Aerosols furnish a simple technique for feeding adults with specific substances, without the introduction of the complications involved in the use of culture media. The presence of stained regions in the testis indicates that aerosols of at least some chemicals reach the germ cells. The genetic study of treated flies will show whether this technique is effective in producing mutations.

## CYTOGENETICS OF DROSOPHILA

BERWIND P. KAUFMANN AND HELEN GAY

### MODIFICATION OF X-RAY-INDUCED CHROMOSOMAL REARRANGEMENTS

*Use of near infrared radiation.* Although radiation geneticists have outlined the more general aspects of the process whereby the activating energy of ionizing radiation induces alterations within a chromosome that culminate in its eventual breakage, the sequence of molecular changes by which this end is reached remains unknown. Since breakage may be followed by recombination, it follows that the process of disruption by X-rays involves a loosening rather than a destruction of those bonds that normally serve to maintain the linear continuity of the chromosome. The experimentally induced recombination types show such patterns of re-alignment of parts as presumably have occurred in phylogeny, but the techniques used have failed so far to furnish a clear understanding of the methods by which these changes have occurred in nature.

Certain aspects of the cycle of chromosome breakage and recombination have been elucidated by altering the conditions, such as rate and temperature, under which the ionizing radiation was delivered. On theoretical grounds it appears possible, therefore, to modify the capacity for reattachment of the bonds loosened by the ionizing radiation if supplementary treatment is given prior to the time that new combinations are established. *Drosophila* appears to be especially well suited for experiments of this type, since irradiated chromosomes of the mature spermatozoa do not combine to form new arrangements until after the sperm has entered the egg in the process of fertilization (Year Book No. 39). Irradiated males can be kept for several days before mating, so that long intervals of time are available in which efforts may be made to alter experimentally the capacity of the regions of breakage to recombine or to undergo restitution. Any

factor promoting restitution prior to the time of recombination should decrease the number of potential breaks, and thereby increase the frequency with which sperms transmit in fertilization an unaltered group of chromosomes. Supplementary treatment, if it were effective in disrupting the chromosome and "sealing" the broken end, would likewise reduce the proportion of detectable alterations.

Proceeding on these assumptions, a series of experiments were initiated (Year Books Nos. 41, 42) to measure the effects of the ultraviolet and near infrared parts of the spectrum on X-ray-induced chromosomal rearrangements. The projects were carried out in cooperation with Dr. Alexander Hollaender, of the National Institute of Health, who designed the apparatus used for treating the flies. The method of biological assay involved cytological analysis of the salivary-gland chromosomes of the F<sub>1</sub> larval progeny of irradiated fathers mated with virgin females of the same (Oregon-R) stock of *D. melanogaster*.

In the first experiments (Year Book No. 41) 4000 roentgens of X-rays were given in

when intercalated between the two fractions of X-ray treatment, it was effective in reducing the frequency of chromosomal rearrangements in proportion to the time of treatment. Subsequent experiments have shown that the reduction with time is to be attributed to an accelerating effect of the near infrared radiation on those processes that make available for copulation sperm that was not mature at the time of X-ray treatment.

Post-treatment with near infrared does not seem to be effective, therefore, in eliminating or modifying the potential breaks induced by X-rays. But a repetition of the fractionation experiment so designed as to test only spermatozoa that were mature at the time of treatment gave a frequency of rearrangement in excess of that observed in the X-ray controls. Inasmuch as fractionation of the X-ray dose involves pre-treatment as well as post-treatment with near infrared, a series of tests was run in which exposure to near infrared preceded 4000 roentgens of X-rays. The combined data from 5 series of experiments are presented in the accompanying table.

FREQUENCY OF CHROMOSOME BREAKAGE

Type of treatment	Total sperms tested	No. with rearrangements	Per cent sperm showing changes	No. of breaks observed	Breaks per 100 sperms	Mean no. of breaks
Near infrared followed by 4000 r	721	312	43.27 ± 1.84	850	117.89	2.72 ± 0.064
4000 r alone .....	549	169	30.78 ± 1.97	435	79.23	2.57 ± 0.075
Diff. %/S. E....	....	....	12.49 / 2.70 = 4.6	....	....	0.15 / 0.098 = 1.5

two equal fractions at 16-day intervals, and in the intervening period the flies were exposed to near infrared radiation for either 72, 144, or 216 hours. The near infrared radiation when used alone produced no detectable chromosomal changes in a sample of 100 pairs of glands examined; but

There seems to be little question, from these data, that pre-treatment with near infrared is a method of increasing the yield of detectable chromosomal alterations in *Drosophila*. The frequency of rearrangement and that of breaks per total sperm tested are of the same order of magnitude

as those induced in earlier experiments by a dose of 5000 roentgens of X-rays. But when a comparison is made, using the  $\chi^2$  test, of the proportions of simple and complex rearrangements, they resemble a 5000-r treatment less than they do one of 4000 r. Thus the effect of the exposure of male flies to near infrared seems to be to sensitize the chromosomes of the sperm so that the number of potential breaks induced by 4000 r of X-rays, and the consequent opportunities for recombination, are increased without altering the proportions of 2-break, 3-break, and multiple-break combinations characteristic of a 4000-r treatment. A consideration of the distribution of the induced breaks indicates, moreover, that the increased yield of chromosomal aberrations is not due to selective sensitization of any one chromosome or part thereof.

Breaks that are detectable by analysis of salivary-gland chromosomes represent but a residue of the larger number of potential breaks induced by the X-rays, since some patterns of recombination lead to unbalanced, inviable nuclei in subsequent generations. An effective measure of these "dominant lethals" may be obtained by determining the proportion of individuals that die in embryonic stages. Since only about 15 per cent of the eggs hatched following an X-ray dose of 4000 r, a dose of 2000 r was used following exposure of the males to near infrared rays. The accompanying table presents data of all egg counts.

HATCHABILITY OF EGGS

Type of treatment	Total eggs deposited	Unhatched 36 hrs. later	Per cent failing to hatch
None (controls)....	7,047	478	6.8
Near infrared alone (48 hrs.).....	14,272	1,901	13.2
2000 r alone.....	9,214	4,480	48.6
Near infrared (48 hrs.) + 2000 r....	9,562	5,096	53.3

Near infrared radiation of sperm, although inducing no appreciable number of chromosomal rearrangements (none among 100 sperms tested), slightly increases the percentage, in comparison with the controls, of eggs that fail to hatch. The end result is such as might be obtained if a small percentage of the sperm were inactivated and, although penetrating the egg, were unable to ensure fertilization. We have not sectioned a series of eggs to determine whether those that fail to hatch have been fertilized, but inactivation of some spermatozoa does not account for the augmented break frequency obtained following the combined treatment, nor does differential inactivation seem probable when we recall that adult male flies exposed to near infrared rays for as long as 216 hours show no apparent physiological disturbances or reduction in viability. Another possible mode of action of near infrared radiation is the rearrangement of certain molecular configurations within the chromosome so that the bonds maintaining the linear continuity of the chromosome are uncoupled more readily by the ionizing radiation than if such pre-treatment had not been given. Near infrared radiation does increase the body temperature of *Drosophila* during the period of exposure. By means of a thermocouple designed by Dr. J. Gordon Carlson, working with Dr. Hollaender at the National Institute of Health, it has been determined that the temperature of the fly during exposure is elevated about  $7^{\circ}$  C. The flies used in the studies here reported attained temperatures of at least  $29$  to  $30^{\circ}$  C., but survived for as long as 9 days without loss of fertility. This is made possible by the design of the treatment chamber, which is fitted within a coil that carries circulating water (temperature,  $19^{\circ}$  C.) and prevents excessive accumulation of heat in the culture medium or enclosed air.

Since near infrared radiation provides a method that essentially increases the temperature range within which normal viability of *Drosophila* is maintained, its effect on irradiated chromosomes at the time of their recombination has also been measured. Females inseminated by sperm from X-rayed males were exposed to the beam of near infrared rays during oviposition. The eggs deposited by these females completed the early cleavage stages while exposed to the radiation, and gave a significantly higher frequency of chromosomal rearrangements than those held at 18° C.

recommend its use in experiments designed to alter the frequency of X-ray-induced breakage (see Year Book No. 41). Accordingly, males of the Oregon-R stock of *D. melanogaster* were given 4000 r of X-rays and exposed shortly thereafter to ultraviolet radiation of wave length 2537 Å for 10 minutes. To facilitate penetration of the ultraviolet rays, the abdomens of the flies were flattened between quartz plates so as to bring the testes closer to the ventral body surface. Frequencies of chromosomal breakage are presented in the accompanying table.

FREQUENCY OF CHROMOSOME BREAKAGE

Treatment (X-ray, 4000 r; 2537 Å, 10 mins. exposure)	Total no. sperm tested	No. with rearrange- ments	Per cent sperm showing changes	No. of breaks detected	Breaks per 100 sperm	Mean no. of breaks
Ultraviolet alone.....	146	....	.....	....	....	.....
X-ray alone.....	128	38	29.7 ± 4.04	108	84.4	2.84 ± 0.19
X-ray + ultraviolet:						
(a).....	55	8	14.5 ± 4.75	20	36.4	.....
(b).....	51	8	15.7 ± 5.09	27	52.9	.....
(c).....	49	12	24.5 ± 6.14	25	.51.0	.....
(d).....	44	12	27.3 ± 6.72	33	75.0	.....
(e).....	39	11	28.2 ± 7.21	24	61.5	.....
(f).....	51	16	31.4 ± 6.50	39	76.5	.....
Total X-ray + ultraviolet..	289	67	23.2 ± 2.48	168	58.2	2.51 ± 0.13

during the same period. (See Year Book No. 42.) These results suggest that the higher temperature accelerates those movements of the chromosomes that facilitate chromosome recombination. In this connection it is interesting to note that eggs exposed to a temperature of 28° C. show values in frequency of recombination and in the complexity of the resulting rearrangements intermediate between the 18° C. and the near infrared samples.

*Effect of ultraviolet radiation of wave length 2537 Å.* The selective absorption of monochromatic ultraviolet radiation by various components of the chromosome

The considerable variability in the frequency of chromosomal alterations obtained following the combined treatment is presumably attributable to varying degrees of penetration of the ultraviolet quanta. Nevertheless, when the total data are compared with those for the X-ray controls, the difference in the percentages of altered sperms is 1.9 times its standard error, and therefore at the threshold of significance. In respect to the proportions of various types of rearrangement observed, the results of the combined-treatment series (4000 r + 2537 Å) approximate more closely those of a 3000-r X-ray treatment

than those of a 4000-r treatment alone ( $P = \text{ca. } 0.95$  when obtained from  $\chi^2$ ).

Despite our inability to determine with any degree of precision the amount of energy reaching the mature spermatozoa of the testes, we feel that the data here presented indicate that ultraviolet radiation that penetrates spermatozoa previously exposed to ionizing radiation may so affect the chromosomes as to produce fewer chromosomal rearrangements than would have been obtained if ultraviolet radiation had not been used.

Whether the ultraviolet alters the chromosomes by inhibiting recombination or by increasing the amount of restitution may possibly be determined by measuring the frequency of dominant lethals. Counts of numbers of eggs that fail to hatch have been made for both the ultraviolet and X-ray controls, but data from the combined treatments are at present too meager to present a satisfactory answer to the problem.

Ultraviolet of wave length 2537 Å is absorbed primarily by nucleic acids, but whether the action here reported may be attributed to absorption by the ribose nucleic acid—as Swanson (Genetics, vol. 27, 1942) suggests to explain the effects of wave length 2537 Å on X-ray-induced breaks in the pollen-tube chromosomes of *Tradescantia*—or by the deoxyribose nucleic acid or other components of the chromosome remains to be determined. The spermatozoon of *Drosophila* presumably has a high content of the deoxyribose type, and, according to Schultz, is not affected by ribonucleose under conditions that permit digestion of the matrix of the salivary-gland chromosomes. Answers to problems of this type can possibly be given by an extended study of the comparative effects of ultraviolet radiation of different wave lengths.

#### SPONTANEOUS MUTATION RATE IN *DROSOPHILA*

Radiation genetics has given many clues, if not an answer, to the problem of the nature of the mutation process. Further information may be gained by analysis of various factors influencing spontaneous mutation rates. Ten years ago N. W. Timoféeff-Ressovsky presented data showing that the percentage of mutations occurring in the chromosomes of *Drosophila* varies with the age of the spermatozoon. We have carried out similar experiments during the past year with the assistance of Miss Katherine Tulloch and Mr. B. N. Kaufmann. The frequency of lethal mutation in the X chromosome of the Swedish-b stock of *D. melanogaster* was determined by the standard ClB method. All stocks and experimental materials were kept at 22° C. Males were selected within a few hours of their emergence, stored for either 1 day, 16 days, or 32 days, and then placed for 1 day with virgin females of the ClB stock. The sperm from males 1-2 days after emergence gave 5 lethals out of 3545 sperms tested ( $0.141 \pm 0.063$  per cent); that from males 16-17 days after emergence, 11 lethals out of 3471 ( $0.317 \pm 0.095$  per cent); and that from males 32-33 days after emergence, 30 lethals out of 5248 ( $0.5716 \pm 0.104$ ). The 1-2-day and the 32-33-day samples are significantly different; together with the 16-17-day material they indicate a relation of mutation to passage of time that is essentially a linear proportionality. These data were obtained by testing mature sperms (which presumably are neither resorbed nor ejaculated while the males are stored), so that we may be measuring mutation rate in nondividing chromosomes. Other experiments bearing on this problem are now in progress.

### CHROMOSOME BREAKAGE AND RECOMBINATION

In the analysis of the chromosome rearrangements obtained in the experiments outlined in the preceding pages, the positions of a considerable number of breaks have been determined. For the X chromosome more than 1400 points of breakage have been localized with respect to the lettered subdivisions of Bridges' salivary-gland-chromosome map. Details concerning the distribution of the greater part of this total were presented in Year Book No. 43. Analysis of the accumulated data has been continued, with a view to determining the patterns of recombination between these breaks and those in other chromosomes. Data accumulated in an earlier study (Year Book No. 37) had led to the conclusion that breaks are distributed among the chromosomes essentially at random (assumedly in accordance with the random distribution of the ionizing radiation), but that the opportunity for recombination at any region of potential breakage depends on spatial relations that favor exchange within a chromosome limb (intrabrachial inversion) as compared with exchange between limbs (interbrachial inversion and reciprocal translocation). With the large body of data now available we are in a better position to ascertain whether the breaks determined by analysis of salivary-gland chromosomes represent a random sample of the potential breaks originally induced.

The breaks involved in interchanges with the X chromosome are scattered among the autosomes essentially at random with respect to length either of mitotic chromosomes or of salivary-gland chromosomes. The proportion of rearrangements restricted to the X chromosome is larger, however, as compared with exchanges between the X chromosome and

the autosomes, than would be expected if recombination were at random. Moreover, the ratio of number of X-chromosome inversions to number of translocations between the X and the autosomes differs markedly according to whether heterochromatic or euchromatic regions are involved. The analysis—which up to the present has included only two-break cases, and requires further confirmation—suggests that differences may exist in the time, with respect to the movement of the chromosomes, at which potential breaks in euchromatin and heterochromatin first become available for the initiation of recombination.

The pattern of recombination within the chromosome may be measured by determining frequencies of inversions of different lengths. Considered in terms of units as large as the division, the frequencies depart only slightly from values expected if recombination were at random ( $P$  from  $\chi^2$  is almost 0.03). When one break occurs in the proximal heterochromatic region (division 20), the separated ends apparently may combine with equal facility with any other available broken ends within divisions 1 to 19. Inverted sections restricted to these divisions can be measured in terms of numbers of subdivisions encompassed. Plotted against values expected on random distribution, a  $P$  of ca. 0.005 is obtained, which suggests that the data do not adequately fit this hypothesis. Of the various possible lengths (ranging from 0 to 113 subdivisions), the highest frequencies were found in the inversions of 12 or 13, of 25 or 26, and of 42 or 43 subdivisions in length. This suggests that a pattern of coiling may exist within the X chromosome at the time of recombination that increases the chances of reunion of parts separated by the distance of one full turn. This increase is slight, however, since an inversion was observed

in which both breaks occurred in the same subdivision, another as long as 111 subdivisions, and others of almost all intermediate lengths.

The extensive data of the present study enable us, therefore, to interpret more adequately the conclusions reached in earlier work. It is now clear that patterns of break distribution and recombination that were obscured by analysis in terms of the divisions of the salivary-gland chromosome are revealed when smaller units such as the subdivisions are considered. By plotting the distribution along the X chromosome of breaks involved in exchanges with other breaks in either proximal or

intercalary heterochromatic regions, it was found that the broken ends produced by a break in heterochromatin may combine freely with all other regions within the chromosome, either euchromatic or heterochromatic. These conditions suggest that the breaks identified by analysis of salivary-gland chromosomes represent in their distribution essentially a random sample of the potential breaks originally induced. For a more complete understanding of the various factors involved in recombination, studies paralleling those here summarized will be required for the limbs of the various autosomes.

## GENETIC STRUCTURE OF NATURAL POPULATIONS

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Evolutionary changes in nature are mostly too slow to be perceived within a human lifetime. This fact was recognized by pioneer evolutionists, and most biologists took it for granted until recently. Darwin pointed out that the transformations brought about in domestic animals and plants by artificial selection are relatively rapid, but he conceded that the process of evolution in the wild is something to be inferred rather than observed. This concession need no longer be made. Under some conditions rapid changes do occur in nature. Recent work on micro-organisms shows that the long-recognized phenomena of bacterial adaptation resolve into the same mutational and selectional components that bring about evolutionary changes in other organisms. Entomologists have recorded the occurrence of genetic changes in some insect pests; these changes adjust the insects to the environment as altered by man. Finally, some wild species have been shown to undergo rapid genetic changes, which are geared to the annual climatic cycle, and which represent adap-

tive responses to seasonal alterations in the milieu. The results of studies on a case of this last category have been mentioned in Year Books Nos. 39, 40, and 43, and they are reviewed below jointly with new data. This case has the unique advantage that the changes known to take place in nature can be reproduced in part in laboratory experiments.

### SEASONAL CHANGES IN THE GENETIC COMPOSITION OF POPULATIONS

Populations of the fly *Drosophila pseudoobscura* which inhabit the Andreas Canyon, Piñon Flats, and Keen Camp localities on Mount San Jacinto, California, have been sampled repeatedly during four consecutive breeding seasons (1939-1942). Three types of third chromosome—called Standard, Chiricahua, and Arrowhead—are found commonly, and two further types rarely, in all the populations. These chromosomal types differ in inversions of blocks of genes. The carriers of the different types interbreed at random; inversion

homozygotes and heterozygotes occur in nature. The relative frequencies of the chromosomal types are different in the three populations. The most important fact for us, however, is that these frequencies change from month to month, the changes being cyclic. The data for the four years of observation at Piñon Flats are summarized in the accompanying table.

FREQUENCIES (IN PER CENT) OF THE THREE COMMON CHROMOSOMAL TYPES IN THE PIÑON FLATS POPULATION

Month	Standard	Chiricahua	Arrowhead	No. chromosomes examined
March.....	47.2	28.6	18.1	496
April.....	46.2	23.6	24.9	449
May.....	33.6	31.3	29.0	642
June.....	29.2	35.9	30.6	630
July-August.....	42.3	27.3	26.3	388
September.....	47.3	26.6	22.2	338
October.....	54.1	16.6	25.3	150
November-December.....	41.7	25.0	27.8	180

It can be seen that Standard chromosomes are frequent during autumn and winter, become less prevalent in spring, reach a minimum in June, and increase in frequency during the summer. Chiricahua chromosomes follow a path opposite to that of Standard. The behavior of Arrowhead is erratic. The population at Andreas Canyon undergoes changes qualitatively similar to those at Piñon Flats. No seasonal changes have been observed at Keen Camp, although this locality is only about 15 miles distant from Piñon and from Andreas.

As indicated in Year Books Nos. 40 and 43, these data suggest that, in the Piñon Flats and Andreas Canyon populations, the flies with Standard chromosomes are

better adapted to the summer environment than flies with Chiricahua chromosomes, whereas in spring the conditions are reversed. Accordingly, natural selection augments the frequency of Standard chromosomes in summer, and of Chiricahua chromosomes in spring. In autumn and winter, the three chromosomal types are equivalent.

The data given in the table above show that the frequency of Standard chromosomes decreases by about one-third between March-April and June, and increases by about one-half between June and August-September. Although *Drosophila pseudoobscura* breeds rapidly for an insect, the time intervals just indicated can correspond to hardly more than three generations. The intensity of natural selection necessary to bring about changes so great in so short a time must be very high; i.e., the survival or reproduction rates of the carriers of the different chromosomal types must be quite different. The selection coefficients involved here must be of a higher order of magnitude than those customarily assumed by theorists to be effective in bringing about evolutionary changes in nature. This is very fortunate indeed, because high selection differentials may be verified in experiments, whereas the small ones are not detectable experimentally; this latter circumstance has been, ever since the time of Darwin, the weakest point of the theory of natural selection.

#### NATURAL SELECTION IN ARTIFICIAL POPULATIONS

Artificial populations with different proportions of flies having the three chromosomal types mentioned above have been kept in the "population cages" described briefly in Year Book No. 43. Suffice it to state here that the populations in such cages grow rapidly to a maximum size

compatible with the amount of food supplied, and remain more or less constant in numbers thereafter. The numbers of eggs deposited in a cage, however, are very much greater than the numbers that can develop to adult insects. Hence, the competition for survival is keen in the population cages. If the original population consists of two or more genetic types with unequal adaptive values, the strong types increase, and the weak ones dwindle in numbers. Nineteen experiments with population cages have been completed up to the present, all with flies whose ancestors were collected at Piñon Flats, California. In some experiments the composition of the natural population of Piñon Flats has been artificially reproduced, as far as relative proportions of the chromosomal types are concerned.

The data summarized in the next table (p. 130) are representative of all those experiments carried at constant or fluctuating temperatures above 21° C. Population cage no. 18 was started on October 23, 1944, with an initial population of about 20 per cent Standard, 36 per cent Chiricahua, and 44 per cent Arrowhead chromosomes. By late February of 1945, the proportion of Standard had approximately doubled, and that of Chiricahua had been reduced to around 25 per cent. Cage no. 19 was started on November 15, 1944, with about 38 per cent Standard, 62 per cent Chiricahua, and no Arrowhead chromosomes. By late February of 1945, the proportions of Standard and Chiricahua chromosomes had been approximately reversed. If the initial mixture contains Standard and Arrowhead, but no Chiricahua, Arrowhead is displaced by Standard. But in a mixture of Arrowhead and Chiricahua without Standard, Arrowhead displaces Chiricahua.

These changes observed in population cages are obviously analogous to those

taking place in the natural population of Piñon Flats in summer—Standard displacing Chiricahua chromosomes, and Arrowhead more or less holding their own. Precisely what physiological properties of flies with Standard chromosomes make them superior to those with Chiricahua chromosomes in population cages kept at temperatures above 21° C. is not known; nor is it known whether or not these same properties are responsible for the differential survival of the flies in the natural populations. It may be regarded as an established fact, however, that the carriers of Standard, Arrowhead, and Chiricahua chromosomal types possess sharply different adaptive values in at least some environments. The relative frequencies of these types in populations are governed by natural selection.

Quite different is the outcome of experiments carried on at low temperatures. The relative frequencies of the chromosomal types remain constant, within the limits of experimental errors, in population cages kept at 16.5° C. Therefore, the adaptive values of the different chromosomal types seem to be approximately alike at 16.5° C., although, as we have seen, they are sharply different at higher temperatures. This result agrees very well with the known behavior of the natural populations of Piñon Flats and Andreas Canyon, where the chromosomal types remain nearly constant in frequency during autumn and winter, when the temperatures in the environment of the flies are low. During spring the natural populations undergo a different type of change; the frequencies of Chiricahua chromosomes increase and those of Standard decrease. Attempts to reproduce these changes in population cages have been unsuccessful so far. In all the experiments at the low temperature the relative frequencies of the chromosomal types remained constant, whereas at high tempera-

CHANGES OBSERVED IN ARTIFICIAL POPULATIONS KEPT AT FLUCTUATING TEMPERATURES  
AVERAGING ABOUT 26° C. THE FIGURES SHOW THE FREQUENCIES, IN PER CENT,  
OF THE CHROMOSOMAL TYPES

TIME	EXPERIMENT 18			EXPERIMENT 19	
	Standard	Chiricahua	Arrowhead	Standard	Chiricahua
October 23, 1944.....	19.9	36.5	43.6	.....	.....
Mid-November 1944.....	33.3	39.3	27.3	38.3	61.7
Mid-December 1944.....	37.7	33.7	28.7	53.0	47.0
Mid-January 1945.....	39.3	30.7	30.0	63.3	36.7
Late February 1945.....	44.3	25.7	30.0	60.3	39.7
Late March 1945.....	42.0	19.0	39.0	65.3	34.7
Late April 1945.....	46.7	23.0	30.3	65.3	34.7
Early June 1945.....	56.4	16.3	27.3	70.4	29.6

tures the frequencies of Standard rose and those of Chiricahua declined. This occurred regardless of whether the temperatures were constant or fluctuating, whether the cages were exposed to light or kept in the dark, whether fresh food was introduced into the cages at short or at long intervals.

The mode of action of natural selection on the chromosomal types is interesting. A mathematical analysis of the data has been made by Professor Sewall Wright, of Chicago. He found that, at high temperatures, the adaptive value of Standard/Chiricahua heterozygotes is highest, that of Standard homozygotes lower, and that of Chiricahua homozygotes lowest. Such being the case, Standard chromosomes can never replace Chiricahua completely in any population. The end result of the selection process is the establishment of an equilibrium between Standard and Chiricahua chromosome types. The relative frequencies of heterozygotes and homozygotes at equilibrium are such that the population as a whole attains the optimal adaptive level. Thus, if only Standard and Chiricahua chromosomes are present, the equilibrium is established when 65-70 per cent of the chromosomes are Standard and 30-35 per

cent Chiricahua. It follows that, at high temperatures, in population cages with initial mixtures containing more than 70 per cent Standard and less than 30 per cent Chiricahua chromosomes, the frequencies of Standard must diminish, and those of Chiricahua must rise. This expectation must be tested experimentally.

#### THE GENETIC BASIS OF THE SELECTIVE DIFFERENTIALS

Two hypotheses may be put forward concerning the differences in adaptive value observed between carriers of the different types of third chromosome. First, the gene arrangement in a chromosome may influence the properties of the organism through position effects. Inversions of blocks of genes change the gene arrangement in the chromosome, and hence may change the properties of the body. Second, a chromosomal type may become associated, in a given population, with a certain constellation of genes. The adaptive properties of a chromosomal type would, then, be determined by the genic variants which it happens to carry.

According to the first hypothesis, the chromosomes of a given type must have similar adaptive properties wherever found.

If the second hypothesis is correct, chromosomes of the same type found in populations of different geographic origin may possess different properties. Since all the experiments so far have been done with chromosomes derived from the Piñon Flats population, neither hypothesis can be regarded as established. The second hypothesis is favored, however, by the fact that no cyclic seasonal changes in the frequencies of the chromosomal types are known at Keen Camp. The population of this locality contains the same chromosomal types as those found at Piñon Flats and Andreas Canyon, where changes do occur. Furthermore, chromosomes with different gene contents are known to be present in these populations. The experiments to be reported below show how great is the variety of these chromosomes.

Many chromosomes found in natural populations carry recessive genes which, when homozygous, reduce the viability of their carriers. The reduction may vary from a barely perceptible diminution of the viability to complete lethality. Furthermore, the effects of a given chromosome on viability are often modified very greatly by the environment (see Year Book No. 41). For example, individuals homozygous for the second chromosome no. 1015 from Andreas Canyon have a viability only slightly below normal at 16.5° C., but they are semilethal at 21°, and completely lethal at 25.5°. Here, then, is a good analogy with the behavior of the different types of third chromosome; for, as we know, flies with the Standard gene arrangement have a higher adaptive value than those with the Chiricahua arrangement in summer, a lower value in spring, and an equivalent one in winter. On the other hand, homozygotes for the second chromosome no. 975 from Andreas Canyon, or for no. 863 from Piñon Flats, are normally viable at all three temperatures.

By means of appropriate crosses, flies were obtained which carried (were heterozygous for) both second chromosomes Andreas 1015 and Piñon 863. Such flies may transmit to their offspring either the chromosome Andreas 1015, or Piñon 863, or chromosomes compounded from segments of these two by crossing over. Ninety-six males were taken at random from among the offspring of females of the genetic constitution just indicated. The second chromosomes of these males were examined for their effects on the viability of homozygotes. When the experiment was done at a temperature of 25.5° C., 35 out of the 96 chromosomes tested proved to be lethal when homozygous. These chromosomes seem to resemble the ancestral Andreas 1015. Only 8 chromosomes gave normally viable homozygotes, resembling the ancestral Piñon 863. Of the remainder, 21 chromosomes were extreme semilethals, 13 were less extreme semilethals, and 9 gave subnormal viabilities outside the semilethal range. The 56 chromosomes that behaved as complete lethals at 25.5° were retested at 16.5° C. In this experiment, 47 chromosomes gave almost normally viable homozygotes. Their behavior is thus identical with that of Andreas 1015. Three chromosomes, however, remained lethal, and 6 chromosomes gave distinctly subnormal viabilities at the low temperature.

A great variety of chromosomal types with quite different reaction norms, therefore, can be produced by crossing over between two chromosomes obtained from natural populations. An even more striking example of this phenomenon is offered by the cross involving the second chromosomes Andreas 975 and Piñon 863. As was stated above, both of these chromosomes give homozygotes that are normally viable at the three temperatures tried. Yet, among 22 crossover chromosomes tested,

3 chromosomes proved to be lethal and 3 others semilethal at 25.5° C. It follows that chromosomes which are lethal when homozygous can be produced through recombination of the genes of chromosomes which normally give viable homozygotes. Such lethals, obtained by recombination, may be called "synthetic lethals."

The variety of chromosomes with different gene contents actually available and potentially possible in natural populations is evidently enormous. Even if only a few chromosomes were available to begin with, crossing over would constantly supply new gene combinations. Some of these gene combinations may be favorable in certain environments, other combinations in other environments, and still others may be unfavorable. Although it is obviously advantageous to the organism to have the favorable gene combinations retained, a gene combination formed by crossing over is just as easily dissolved by another crossing over. The dissolution may be delayed or prevented, however, if an inversion happens to occur in the chromosome carrying the favorable combination. Inversions may bind together gene combinations present in a chromosome, because they suppress crossing over. In this manner, chromosomal types that arise through inversions may acquire different adaptive properties and different selective values.

It should be kept in mind that the experiments with population cages showed that flies heterozygous for two chromosomes with different gene arrangements have higher adaptive values than do the homozygotes. It follows that natural selection, in wild populations of *Drosophila pseudoobscura*, favors gene combinations which give optimal results in heterozygous compounds with other gene combinations present in the same populations. The gene combinations that insure the highest degree of hybrid vigor are, evidently, those

in the third chromosomes bound by the inversions. Now, different gene combinations may be more or less favored in localities with different environments, even though these localities may be as near each other in space as Keen Camp and Piñon Flats. The different behaviors of the Keen Camp population on the one hand, and of the Piñon Flats and Andreas Canyon populations on the other, may thus be accounted for. Further experiments are needed to settle this problem.

#### INTERSPECIFIC HYBRIDIZATION IN POPULATION CAGES

*Drosophila pseudoobscura* and *Drosophila persimilis* are two closely related species. They are almost indistinguishable in external morphology, yet are easily recognized by their chromosomes as seen in the salivary-gland cells. Their geographic ranges are distinct but overlapping, and the two species live side by side in an extensive territory. They show a partial sexual isolation; that is, when females of both species are confined with males of one of them, a greater proportion of conspecific than of non-conspecific females is inseminated. If, however, an interspecific mating has taken place, hybrids of both sexes are easily produced, and these hybrids seem to be as vigorous as individuals of the pure parental species. The F<sub>1</sub> hybrid males are completely sterile. The F<sub>1</sub> hybrid females oviposit abundantly, and, if inseminated by males of either parental species, give rise to backcross progenies. The viability of the backcross progenies, however, is more or less strongly reduced on account of a deleterious maternal effect (the eggs of mothers with hybrid chromosomes are somehow injured). In laboratory experiments, it is possible to transfer sections of chromosomes of *Drosophila pseudoobscura* to *Drosophila persimilis*,

and vice versa. Nevertheless, no hybrids have been so far encountered in nature, and the available evidence is against the supposition that these species exchange genes in natural populations. This is but an illustration of the general rule: hybridization in captivity is no proof of hybridization in nature.

The "population cages" offer a technique whereby conditions that obtain in natural populations can be approached more closely than is otherwise possible (no claim is being made, however, that natural conditions are duplicated). The problem, then, is: to what extent will *Drosophila pseudoobscura* and *Drosophila persimilis* exchange genes if they live together in the same population cage for several generations? Late in December 1944, 600 wild-type individuals of *persimilis* and 200 orange-eyed *pseudoobscura* were put in one cage, and 600 wild *persimilis* and 300 orange *pseudoobscura* in another cage. The first cage was placed at a temperature of 21° C., and the second at 16.5° C.

On February 3, 1945, the cage kept at 21° contained 4689 adult flies, 464 of them with orange eyes and 4225 with wild-type eyes. Since orange is an autosomal recessive gene, the orange-eyed flies were obviously pure *Drosophila pseudoobscura*. The wild-type flies may have been either *persimilis* or hybrid. The hybrid males can be distinguished from the nonhybrids by dissection and microscopic examination of their testes. Out of 170 males so examined, 10 were hybrids and 160 were *persimilis*. In the total population of the cage, approximately 5.3 per cent were hybrids and 94.7 per cent pure species. The flies were returned to the cage, which was then placed at room temperature.

On March 14, 1945, this cage contained 1321 wild-type and 486 orange-eyed flies. Two kinds of hybrids could now be expected in the cage: *F*<sub>1</sub> generation hybrids

formed by cross-mating of pure *pseudoobscura* and *persimilis* flies, and backcross hybrids derived from the *F*<sub>1</sub> hybrid females formed in the previous generation and mated to males of the pure species. Backcross hybrids might have either wild-type or orange eyes; the *F*<sub>1</sub> hybrids would be all wild-type. They are not always distinguishable by examination of the testes, but many of them can be told apart in this way. In reality, the 50 orange-eyed males dissected were all *pseudoobscura*, whereas among the 117 wild-type males 114 were *persimilis* and only 3 hybrid, probably belonging to the *F*<sub>1</sub> generation. On May 2, the cage contained 133 orange and 1247 wild-type flies. All the orange males (62) were dissected, and proved to be *pseudoobscura*. Of 200 wild-type males dissected, 193 were *persimilis* and 7 were in all probability *F*<sub>1</sub> hybrids.

The absence of backcross hybrids is suggestive. As was stated above, they can be obtained in laboratory experiments, although their viability is low. Their failure to appear in the population cages indicates that the lowering of the viability is lethal under the conditions of crowding and intense competition that obtain in the population cages, and probably in natural populations as well. The *F*<sub>1</sub> hybrid females are mostly fertile in the laboratory, but they are likely to be completely sterile in nature. This makes gene exchange between the species impossible.

The second population cage, kept at 16.5° C., provides, for two reasons, a rigid test of the validity of the above conclusion. First, low temperatures frequently permit otherwise weak or nonviable types of *Drosophila* to survive. Second, the sexual isolation between *pseudoobscura* and *persimilis*, as Dr. Ernst Mayr has discovered, is very weak at low temperatures; consequently, many more hybrids will be produced. On February 3, 1945, this cage

kept in the cold room contained 2971 wild-type and 1083 orange flies. The latter were obviously *pseudoobscura*. Among the 200 wild-type males dissected, 134 were *persimilis* and 66 were hybrids. It is easy to compute that the total population of the cage consisted of approximately 76 per cent pure species and 24 per cent hybrids. On March 30, the cage had 3987 wild-type and 2634 orange flies. The 200 orange males dissected were all *pseudoobscura*. Among 200 wild-type males, 169 were *persimilis* and 31 were apparently  $F_1$  hybrids. It can be computed that the proportion of hybrids in the total population of the cage dropped to about 9 per cent. The experiment was discontinued on June 11, when the cage contained 3390 wild-type and 1937 orange flies. No hybrids were found among 200 orange males dissected. Only 17 hybrids, apparently  $F_1$ , were among 300 normal-eyed males examined. This amounts to about 3.6 per cent of hybrids in the cage population as a whole.

Apart from the production of some first-generation hybrids, apparently no gene exchange takes place between *Drosophila pseudoobscura* and *Drosophila persimilis* in population cages. The proportion of hybrids in the population of a cage does not increase from generation to generation.

As a matter of fact, the cage kept at  $16.5^{\circ}$  C. showed a fairly rapid decrease in the incidence of hybrids with time. If confirmed in further experiments, this progressive reduction of hybridization with time will be a very important finding. For it would constitute an experimental verification of the hypothesis according to which natural selection should strengthen reproductive isolating mechanisms between populations that are exposed to hybridization and that produce hybrids with a lowered reproductive potential.

#### DISPERSION RATES OF DROSOPHILA PSEUDOBOSCURA

Field experiments on the rate of dispersion of *Drosophila pseudoobscura* (see Year Books Nos. 41 and 43) had to be discontinued for a time because of war conditions. They were resumed during the summer of 1945 at Mather, Tuolumne County, California, using some of the facilities of the Division of Plant Biology of the Carnegie Institution. The writer wishes to express his most sincere appreciation to Drs. J. Clausen and H. A. Spoehr, of that Division, for their hospitality at Mather. The experiments should, according to plan, take two years; results will be reported later.

### MOUSE LEUKEMIA

E. C. MACDOWELL, J. J. BIESELE, G. GASIC, M. J. TAYLOR, AND T. LAANES

During the past year, active work on spontaneous leukemia has been confined to the maintenance of experiments previously started. This has been the necessary result of not having a histological technician or a diagnostician, and of having an insufficiency of mice. A major proportion of the mice produced by the unique leukemic strain C<sub>58</sub> have been contributed to a wartime medical research program.

#### SPONTANEOUS LEUKEMIA IN STRAIN BALB

It has long been supposed from casual observation that strain Balb was largely resistant to spontaneous leukemia. The breeding period is long in these mice, and large numbers far older than the most frequent age for leukemia in strain C<sub>58</sub> have been handled. The first actual determination of the incidence of leukemia in a given sample of Balb mice has recently

been completed, with the surprising result that, according to the diagnoses of gross autopsies, nearly 70 per cent have died with leukemia. We are grateful to Dr. M. N. Richter, of New York Post Graduate Medical School and Hospital, for confirmatory microscopic diagnoses of a random sample of 22 of these mice. The reason that this high incidence of leukemia was not anticipated is that the leukemia (as indeed all causes of death) is much later in appearing in this strain than in strain C58. This fact is indicated by the accompanying comparison of average length of life and incidence of leukemia in inbred females of three strains. This table furnishes new evidence of the inde-

STRAIN (FEMALES)	LEUKE- MICS (%)	TOTAL NO. OF MICE	LENGTH OF LIFE (DAYS)	
			Non- leukemic	Leukemic
Balb* . . .	69.3	88	632.0	692.3
Balb† . . .	68.0	25	655.5	679.8
StoLit . . .	15.1	33	678.9	688.0
C58† . . .	90.5	40	482.0	360.3

\* Virgin females.

† Females which had produced young in connection with the foster-nursing experiment previously described.

pendence of longevity and incidence of leukemia, a subject discussed a year ago, in that the relatively long-lived mice of strains Balb and StoLi differ so greatly in the incidence of leukemia, and in that the many leukemics in strains C58 and Balb differ so greatly in length of life.

#### STEROID HORMONES AND TRANSPLANTED LEUKEMIA

Gasic has carried out various experiments with steroid hormones and transplanted leukemia, with the purpose of investigating the possible influence of these hormones on the time of survival and the pathological picture of inoculated mice.

Pellets of hormone, pure or mixed with cholesterol, were inserted subcutaneously into normal males and females and spayed females of strain C58 at the age of one month; the spaying was done at the same time. The cholesterol and the pure hormones—desoxycorticosterone acetate, progesterone, and testosterone propionate—were generously provided by the Schering Corporation. In most of the experiments, leukemic cells of line I were used in doses diluted to 1/256 of standard, which doses are 100 per cent lethal in normal mice of this strain. These doses were given 10, 21, 32, and 60 days after the hormone pellets.

The results indicate that the mice treated with testosterone propionate 32 and 60 days before leukemic inoculation survived a little longer than the controls. In different experiments the averages were from 12 to 18 hours longer. The other two hormones showed no effect on the time of death.

Most of the effects of the hormones on the anatomical pictures at autopsy were those indicated in the literature on normal organs. In mice with pellets of desoxycorticosterone, however, the leukemic spleens were unaccountably large. And in spayed females the small hemorrhages that appear in the lungs very shortly before death from line-I leukemia were reduced in frequency and size; this effect was partially overcome by progesterone and eliminated by testosterone propionate. Histological study reveals that these pulmonary hemorrhagic spots are caused by thrombi rich in leukemic cells; but the pathological mechanism concerned, and the manner in which sex hormones act upon it, are questions for investigation.

Incidental observations showed that total body weight of females was increased by spaying, so that it surpassed that of males by 32 days after the operation. Pellets of testosterone propionate considerably coun-

teracted the effect of spaying. Progesterone has a similar but less striking effect. In leukemic mice the correlation between weights of entire body and liver was high; it was lower between body and spleen; but thymus weights showed no correlation with body weight. The spleen of the leukemic female at death weighed less than that of the male, but spaying females eliminated this difference.

#### ALARM REACTION

In the course of the preceding work, Gasić noted that mice of strain C58, inoculated with leukemic cells of line I, showed a severe involution of the thymus. This observation had been made previously, in experiments on immunity to leukemic cells in this laboratory. But Gasić recognized that this involution and other conditions associated with it were characteristic of a general syndrome described by Selye as the "alarm reaction," which may be elicited by a variety of deleterious conditions and substances. Selye's 1940 list of stimuli known to induce this reaction does not include malignant growths.

After a period of incubation, the inoculated animals show a clinical syndrome resembling shock: lowered temperature, lack of muscular tone and of appetite, sweating, drooping eyelids, and frequently a white lachrymal secretion. Anatomically, the chief features of the well developed alarm reaction are: hypertrophy and other gross changes of the adrenal, involution of the thymus, atrophy of the pancreas, general hyperemia, edema of the serosa, and, less frequently, ulcers and erosion of the digestive tract accompanied by hemorrhages.

The defensive importance of the involution of the thymus, under immediate control of adrenal hormones, has recently been brilliantly elucidated by the experi-

ments of Dougherty, White, and Chase. Not only are antibodies delivered to the blood stream by a hormonal control of the thymus, but normal lymphocytes may transfer specific antibodies to, and receive them from, malignant cells of a transplanted lymphosarcoma. The appearance of the gross phenomenon of thymic involution in certain leukemic hosts raises the question of the possible part this phenomenon may play in induced resistance to leukemic cells.

In approaching the significance of this reaction for the interpretation of leukemic processes as well as for the mechanism of resistance to leukemia, Gasić has studied different experimental conditions and spontaneous cases. He has varied the genetic constitution of the host and the size of the dose of inoculated leukemic cells of lines differing in virulence, number of transfers, and other specific characteristics. In general, the strength of this reaction increases as the survival time is reduced. In spontaneous cases and early transfers, which are relatively chronic with large tumorous lesions, the alarm reaction is mostly undemonstrable. As the acuteness increases in the course of successive transfers, the leukemic lesions become progressively smaller and the alarm reaction more and more distinct. But even with an extremely virulent line of cells, the survival time may be lengthened by reducing the dose. This increases the size of the leukemic lesions and diminishes the expression of the alarm reaction. Certain combinations of genetically foreign hosts and acute leukemias show extreme alarm reactions, with minimum invasion of leukemic cells. The gross changes in adrenal and thymus are somewhat more evident in females than in males. Subsequent study will trace the alarm reaction during the processes of resisting lethal doses of leukemic cells and development of immunity. Does

a lethal dose in an immunized mouse occasion involution of the thymus, without conditions that in themselves might be responsible for death? How different are the causes of death in chronic and acute cases? Does resistance to the destructive aspects of the alarm reaction also destroy leukemic cells? Is the increase in toxic action in the course of successive transfers a result of the increasing proportion of large cells, or a change in a toxic agent carried by the cells?

#### CHROMOSOMES IN LEUKEMIA

In previous years, Bieseile had found the chromosomes of many neoplastic tissues to be larger than, and usually about double the volume of, chromosomes of normal cells of the tissues of origin. Because the number of chromosomally carried plasmosomes in many of the resting nuclei of the neoplasms had doubled, and the frequency of polyplloid mitoses in some tumors was low, it had been tentatively concluded that the enlarged chromosomes of malignant cells were structural multiples of the chromosomes of normal cells.

The new work has tested this conclusion by a study of chromosomes of leukemic and normal tissues of different ages.

In the study of chromosome size in normal tissues, some 1100 metaphase figures have been drawn from 50 albino rats of 6 age groups. The animals were provided by the Fels fund through the courtesy of Dr. E. J. Farris, of the Wistar Institute for Anatomy and Biology. Up to the present, the following scheme of variability in chromosome size has been disclosed. In late embryos chromosomes of the chief organs all measured about one-half cubic micron; the thymus chromosomes, however, were two or three times smaller. After birth the variability was greater: in lymph nodes, spleen, and intestinal epithelium the

chromosomes became smaller with age, in epidermis and lung they remained constant, in kidney they increased in size, and in liver their relative increase was enormous, up to 20 times the size of the smallest thymus chromosomes. The order of tissues in adult rats, according to relative values based on average chromosome volume, is as follows: lymph nodes and spleen, 2; intestinal epithelium, 2+; epidermis and lung, 3; kidney, 4+; liver, 8. This seriation confirms one published earlier from more limited material.

These data yield a provocative insight into the nature and possible function of somatic chromosomes, especially as the two series are paralleled by others, from the literature, dealing with the over-all enzyme activities of adult rat organs and the concentrations of B vitamins, most of which are known to be associated with enzyme systems. The parallelism extends to embryonic organs. In view of the growing knowledge of the relation between gene and enzyme, it seems permissible to repeat here the suggestion that normal chromosomes, in proportion to their mitotic size, might be instrumental in the synthesis of protein apoenzymes of the cell. This would suggest a possibly qualitative differentiation of chromosomes in size and function, according to cell type and age.

These generalizations can probably be applied to the mouse. For example, livers of C58 adults, regenerating after partial surgical removal, contained chromosomes much larger than those in embryonic liver.

It is known, however, that malignant tissues often show reduced enzyme activities and vitamin concentrations. Is the presumed productive effort of the enlarged chromosomes in cancers abortive, being diverted to the benefit of the competitive altered enzyme or "cancer virus" of V. R. Potter's theory? Or is the enlargement of chromosomes in neoplasms of a different

sort from that in normal tissues, perhaps involving the less specific heterochromatin instead of euchromatin? But if the enlarged chromosomes of cancers are actually abnormally multiple in structure, each one must consist essentially of a number of smaller chromosomes, and hence the euchromatin could not have undergone the differentiational enlargement suggested as leading to big chromosomes in normal cells.

Our knowledge of the processes occurring in the enlargement of chromosomes in malignancies is augmented in several ways by the study of chromosomes in leukemia of C58 mice.

First, we find that the development of leukemia reverses the reduction in size of lymphocyte chromosomes, which normally goes on rapidly in early life but more slowly with age. Thus in spontaneous leukemias in 12 animals about 40 weeks old, the average chromosome size in the enlarged mesenteric nodes and spleens was one-third to two-thirds greater than that in 3 coeval controls (0.37 cubic micron). With respect to chromosome size the whole population of dividing leukemic cells seems to have been shifted upward, yet in this regard the leukemic populations of the 40-week-old mice were hardly distinguishable from the normal lymphocyte populations of 9 males about 2 months old. Likewise, the average chromosome volumes in the six current lines of long-transplanted leukemia were about 0.8 cubic micron, much the same as the average for the spleen of the newborn C58. Although the upper limit of chromosome size in the six lines exceeded that in the newborn spleen, there is evidence that its peer may be found in the primitive blood cells of embryonic liver. In but one leukemia, a spontaneous case in a 2-year-old hybrid female, were there chromosomes of a size (up to 2.0 cubic microns) unparalleled in

the normal lymphatic tissues; but this case had other odd features, such as a great deal of aneuploidy and polyploidy instead of the usual uniform diploidy. Evidently in the majority of dividing C58 leukemia cells there are chromosomes whose size is equaled at some stage in the ontogenetic history of normal lymphocytes. Since it is possible that equality of size of chromosomes could disguise an underlying dissimilarity of structure or material, our present observations hardly give us basis for choice between J. S. Potter's concept of an altered rate of differentiation as the fundamental malignant change and the theory of "tangential" differentiation of some other oncologists.

Second, our study demonstrates that the enlargement of chromosomes in malignancies may not be absolute and irreversible, since the size of chromosomes in leukemias appears to be environmentally modifiable. In each of the six transplanted lines, the over-all mean of chromosome volumes in specimens taken from female hosts was smaller by about one-fourth than the mean for male specimens. There was some overlapping, however. That this sex difference in size of leukemic-cell chromosomes may have a hormonal basis is suggested by examination of Gasic's material. For example, in spayed females, half of which bore implanted 12-mg. pellets of pure testosterone propionate for 1 month before inoculation with leukemic cells, the average chromosome volume in leukemic lesions of the 6 animals receiving the hormone was significantly greater than that in the 7 untreated animals. The ranges of chromosome size scarcely overlapped, and the leukemic-cell chromosomes in the spayed females without added testosterone pellets were the size of normal lymphocyte chromosomes in intact males at 7 weeks.

The above observation indicates that in lesions even of highly virulent lines, cells

with small chromosomes may be leukemic. In addition, the smallest chromosomes found in the supposedly totally leukemic lesions of liver were usually but little larger than the mean size of lymphocyte chromosomes within uninoculated animals.

The third contribution made by these studies of leukemia to our knowledge of chromosomes in malignancies is the realization that their enlargement may be gradual. With the exception of the aberrant case mentioned above, the frequency distributions of metaphases according to average chromosome volume in the 60 leukemic specimens studied are interpretable as unimodal, rather than polymodal as in many cancers. The increase in chromosome volume from the normal condition through chronic spontaneous leukemia to its highly virulent transplanted derivative also promises to be a continuous one. A slow hypertrophy of the chromosomes in mouse leukemia, rather than a sudden doubling in volume such as occurs in mouse skin painted with carcinogenic hydrocarbons, would suggest that a more subtle change than an abrupt structural modification by doubling of strand number may be responsible, not only in leukemic cells but also in cells of other types of malignancy.

Direct studies of structure on the chromatid level, by uncoiling chromosomes and allowing sister chromatids to fall free of one another, are in progress. Should it be determined that the chromosomes of leukemic cells contain no more than two chromatids, as would seem likely

from the earlier observations of Claude and Potter on chromatin threads isolated from leukemic cells, and that the leukemic-cell chromatid gives no visible evidence of a more complex structure than that of the normal lymphocyte chromatid, then the explanation of larger size of chromosomes in leukemic cells would have to be sought on a level other than that of the chromatids or their immediate precursors —perhaps ultimately on the level of molecular amount or kind. On this level a gradual size increase would be readily explicable, but it should not be interpreted offhand as the exact reversal of the ontogenetic diminution.

In summary, we are left with the suggestion that the enlarged chromosomes of C58 leukemia are either immature normal chromosomes or products of differentiation in an abnormal direction. If the latter view be accepted, it is not clear what form the hypertrophy has taken, nor whether the chromosomes are structurally or materially altered. The size of the chromosomes is fairly labile and responsive to certain environmental conditions. Apart from the question of leukemia, the demonstration that the size of mouse chromosomes can be influenced by means of hormones would seem to be of importance in chromosomal physiology. This is especially true in view of the suggestion that there is a differentiation of chromosomes according to cell type and age, in which the size of the chromosomes reflects their activity in some part of the manufacture of intracellular enzymes.

#### ENDOCRINE STUDIES

O. RIDDLE, W. F. HOLLANDER, M. R. McDONALD, E. L. LAHR, AND G. C. SMITH

During the past year most members of this group have shared in the conduct of research, and also assisted in the preparation of manuscripts dealing with previous

research. In March Mr. Lahr left to become associated with the School of Dentistry of New York University. At intervals during the year Professor Hoyt S. Hop-

kins, of the Department of Physiology, New York University, rendered further assistance in summarizing the results of our extended study on heat production in doves and pigeons. Manuscripts constituting a small volume, "Studies on carbohydrate and fat metabolism, with especial reference to the pigeon," were completed in January. These studies by Riddle and associates will appear as publication 569 of the Carnegie Institution of Washington. Manuscripts dealing with our prolonged studies on races of doves and pigeons, "Endocrines and constitution in doves and pigeons," were completed later. In July, substantially the whole of our program of research was brought to a conclusion.

#### THE EFFECT OF REPRODUCTION AND ESTROGEN ADMINISTRATION ON THE PARTITION OF CALCIUM, PHOSPHORUS, AND NITROGEN IN PIGEON PLASMA

A partial report was made last year on the partition of those plasma components that might be capable of binding the large increases in calcium observed in pigeon plasma during periods of egg production or after injection of estrogens. These studies by McDonald and Riddle have now been completed and the results published. Changes in the various calcium, phosphorus, and nitrogen components of plasma were studied (a) in 75 adult female pigeons during the reproductive cycle and (b) in 31 normal, 4 fasted, 13 parathyroidectomized, and 4 hypophysectomized pigeons injected with estrogens. Birds of both sexes, varying in age from 1.5 months to 5 years, were used in the latter study; 65 additional pigeons (46 normal, 13 parathyroidectomized, and 6 hypophysectomized) were used as controls.

No significant differences occurred in either ultrafiltrable calcium, ultrafiltrable

inorganic phosphorus, or nonprotein nitrogen during the reproductive cycle or after the injection of estrogens. Nonultrafiltrable calcium, nonultrafiltrable inorganic phosphorus, lipid phosphorus, and protein phosphorus all increased markedly from 4 days before the ovulation of the first ovum until 2 days after the ovulation of the second (last) ovum. Similar, and even greater, increases resulted (in all the types of pigeons studied) from the daily injection of from 0.25 to 0.5 mg. estradiol benzoate for from 4 to 25 days. Small increases in protein nitrogen were noted under these conditions. Endogenous estrogens, as postulated by Riddle in 1927, are probably responsible for the increased plasma calcium, phosphorus, and nitrogen found during the reproductive cycle.

Calculations of the regression equations and correlation coefficients between the various plasma components that increased owing to endogenous or administered estrogens showed that the nonultrafiltrable calcium of pigeon plasma exists in three forms: (a) colloidal calcium phosphate, (b) calcium bound to the phosphoprotein, serum vitellin, and (c) calcium bound to the plasma proteins other than vitellin. Increments in (a) and (b) accounted for all the estrogen-induced increases in nonultrafiltrable calcium. The changes found in the partition of the latter as it increased during reproduction or under the influence of administered estrogens are summarized in figure 1. In 72 control pigeons, 36 per cent of the nonultrafiltrable calcium occurred as colloidal calcium phosphate, 12 per cent was bound to vitellin, and 52 per cent was bound to the plasma proteins other than vitellin. In 102 estrogen-treated pigeons, however, 37 per cent of the nonultrafiltrable calcium was in the form of colloidal calcium phosphate, only 8 per cent was bound to the plasma proteins other than vitellin, and 55 per cent

was bound to vitellin. Calculations of the calcium-binding capacity of serum vitellin showed that 1 gram of this phosphoprotein can apparently combine with more than 7 mg. of calcium—a value 8 to 9 times greater than that of the other plasma proteins.

trable phosphorus; protein phosphorus was responsible for 36 per cent, and nonultrafiltrable inorganic phosphorus for the remaining 8 per cent.

Benjamin and Hess (1933) noted that barium sulfate adsorbs from plasma a part of the nonultrafiltrable calcium. They

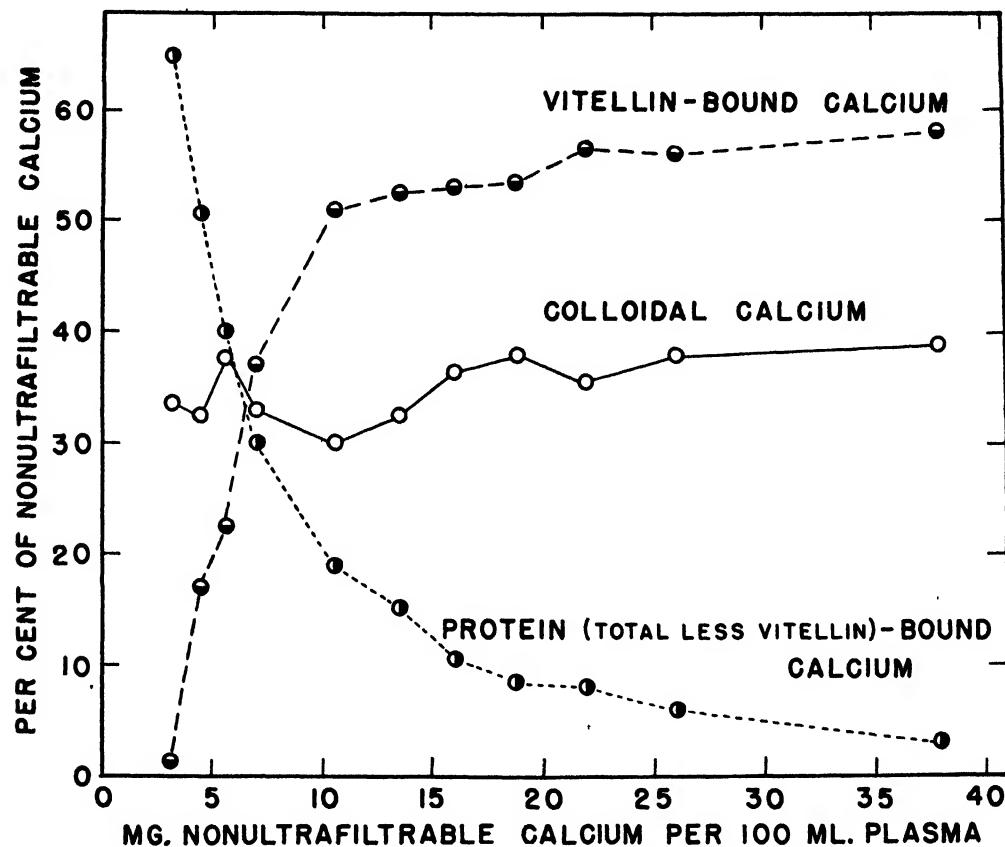


FIG. 1. Analysis, on a percentage basis, of the partition of nonultrafiltrable calcium in pigeon plasma. Each point represents the average of 10 to 29 determinations.

No evidence was obtained for the presence of a phospholipid-calcium complex in the plasmas of pigeons with hypercalcemia due to administered or endogenous estrogens. Lipid phosphorus accounted for 93 per cent of the nonultrafiltrable phosphorus in the plasmas of the control pigeons, but for only 56 per cent of the estrogen-induced increases in nonultrafil-

assumed that this procedure separates the nonultrafiltrable calcium into at least two fractions: protein-bound calcium and an unknown adsorbable complex. Their procedure has been widely used in other laboratories, but the possibility that barium sulfate might also adsorb protein has apparently been neglected. Results obtained in this laboratory on 31 samples of pigeon

plasma confirmed the fact that part of the nonultrafiltrable calcium was adsorbed by barium sulfate. The latter, however, also adsorbed part of the phosphoprotein, serum vitellin. It is therefore impossible to separate, by the procedure of Benjamin and Hess, protein-bound calcium from the adsorbable complex. There is probably a partial adsorption of all the nonultrafiltrable calcium fractions rather than a complete adsorption of one or more specific fractions.

#### ACTION OF THYROXINE ON ESTROGEN-INDUCED CHANGES IN BLOOD CHEMISTRY AND ENDOSTEAL BONE

Estrogens, in addition to increasing the calcium, phosphorus, and lipid content of bird plasma, also induce growth of the oviduct and formation of endosteal bone. Fleischmann and Fried (1944-1945) made the important observation that thyroxine, when administered to immature chicks simultaneously (in equal amounts by weight) with estradiol dipropionate, greatly reduces the ability of the estrogen to increase the plasma calcium, inorganic phosphorus, vitellin, phospholipid, and cholesterol, but does not inhibit the estrogen-induced growth of the oviduct.

Experiments were undertaken in this laboratory to determine (a) whether the results obtained with simultaneous dosage of thyroxine and estrogen in fowl could be duplicated in pigeons, (b) whether such treatment prevents the increase in plasma neutral fat which follows the use of estrogen alone, and (c) whether endosteal bone can be formed under the simultaneous administration of thyroxine and estradiol benzoate. The results obtained have been published. It was found that thyroxine prevented the marked estrogen-induced increases in plasma neutral fat, calcium, inorganic phosphorus, lipid phos-

phorus, protein phosphorus, and total nitrogen. It did not measurably inhibit the ability of estrogen to induce formation of endosteal bone or growth of the oviduct. It therefore seems improbable that thyroxine is a physiological antagonist of estrogens. Its inhibiting action on the estrogen-induced increases in plasma constituents is probably a secondary effect associated with increased metabolism and excretion of calcium, phosphorus, and nitrogen.

The data from these experiments afforded further proof that all the nonultrafiltrable-noncolloidal calcium not bound by the normal plasma proteins is bound by the phosphoprotein, serum vitellin. When the nonultrafiltrable-noncolloidal calcium values for the thyroxine-treated pigeons were plotted against those for protein phosphorus, all the points were found to lie on the regression line previously calculated for 104 estrogen-treated pigeons. When such data for nonultrafiltrable-noncolloidal calcium were plotted against lipid phosphorus, however, none of the points fell on the regression line calculated for 31 normal pigeons injected with estrogen.

#### SOLUBILITY OF THE PLASMA PROTEINS IN ALCOHOL

It was noted last year that at least one of the plasma proteins had the peculiar property of being soluble in acidified mixtures of 3 parts ethanol and 1 part ether. Further investigation of this unusual phenomenon has been possible through the courtesy of Dr. John T. Edsall, who has kindly supplied us with several of the plasma products developed by the Department of Physical Chemistry of the Harvard Medical School from blood collected by the American Red Cross. The study has not been completed, but the results thus far obtained are extremely interest-

ing. They suggest that, if investigations are made over a wide range of pH, it may be found that alcohol solubility is a much more common property of proteins than has previously been postulated.

Crystalline serum albumin was found to be highly soluble in 95 per cent ethanol or mixtures of 3 parts ethanol and 1 part ether, in the presence of small amounts of hydrochloric, nitric, lactic, acetic, or trichloracetic (but not sulfuric) acid. The effect of trichloracetic acid is especially noteworthy, since it completely precipitates albumin from aqueous solutions. Albumin precipitated by trichloracetic acid can still be dissolved by acidified 95 per cent ethanol or ethanol-ether mixtures. The range of pH in which albumin is soluble in 95 per cent ethanol extends from below pH 1.5 to about pH 4.5.

Some, but not all, of the several  $\alpha$  (or  $\beta$ ) globulins were also found to be soluble in acidified 95 per cent ethanol and, to a lesser degree, in ethanol-ether mixtures. Solutions of these fractions, however, unlike those of albumin, are unstable, and the globulins slowly precipitate. The  $\gamma$ -globulins and fibrinogen appear to be insoluble in 95 per cent ethanol in the range of pH thus far studied.

Attempts have been made to develop a method, based on the above observations, for the quantitative determination of albumin and globulin. The results to date are extremely promising. Further refinements of technique should yield a simple procedure for the analysis of these components.

#### PARTIAL MELANISM ASSOCIATED WITH PARATHYROID ENLARGEMENT

Melanism arising from physiological disturbance has not previously been reported for domestic pigeons. A few cases of partial melanism have been observed in

the pigeon colony of this department under circumstances that suggest the nature of the factors intimately associated with the belated appearance of this condition. Hollander and Riddle have found that, on the diet supplied to birds of this colony, a deficiency of sunlight regularly leads to enlargement of the parathyroids and also seems to be concerned in the occasional onset of partial melanism. This melanism had the following characteristics: (a) it was observed only in adult female pigeons of essentially wild-type coloration—gray-blue with black bands on tail and wings; (b) it was definitely partial rather than complete; (c) it first appeared after one or more molts; (d) when the blackening did not involve entire feathers it produced transverse bands on the feathers, not longitudinal streaks such as are typical of mosaic effects.

Five cases of this type of nongenetic partial melanism were observed in adult female domestic pigeons. One similar case was observed in an old male hybrid (*Zenaida*  $\times$  *Zenaidura*) dove after it became unable to fly. Two physiological conditions, slight exposure to sunlight and enlargement of the parathyroids (3 to 6 times normal), were known to be associated with all these six cases of melanism. It is considered probable that these conditions were also responsible for previously reported instances of melanism in caged wild birds. In two instances, plucked melanistic feathers were replaced by normal feathers following the administration of a concentrate of cod-liver oil (vitamin D).

Parathyroid enlargement was shown to occur regularly in young pigeons reared on a mixed-grain diet in the absence of direct sunlight (vitamin D deficiency). Grossly defective ossification of the bones (rickets) of many such pigeons was also noted. These conditions have been observed repeatedly by others in fowl.

Rachitic squabs never have shown melanism even when their parathyroids were very large. A more prolonged deficiency, or an element of aging, therefore, seems to be necessary for the appearance of melanistic feathers. Something more than chance is probably responsible for the fact that this type of melanism has not been observed in a male pigeon. It should be noted that the male's supply of calcium and vitamin D is not subject to the special drains and losses that necessarily accompany egg production in the adult female.

#### INTERSEXUALITY IN MALE EMBRYOS OF PIGEONS

A transient intersexuality in male embryos of certain species of birds has been reported by various investigators. The species in which this condition has been observed include the fowl, English sparrow, blackbird, and pheasant, hawks, and ring doves. This anomaly involves a temporary development of ovarian cortex on the left testes, but usually not on the right testes, of genetic male embryos. Lahr and Riddle investigated the question whether this type of intersexuality exists in the pigeon, and also made a comparison of the conditions found in normal breeds of pigeons with those existing in the special strain of hermaphrodite-producing pigeons developed in this laboratory.

Ovarian cortical tissue is present on the left testes of all pigeons examined at the 14th and 15th days of incubation. In testes from normal races of pigeons (33 cases), ovarian tissue showed degeneration between the 14th day of incubation and the end of incubation (18 days); in such testes the ovarian tissue disappeared completely at or before the time of hatching.

Testes derived from embryos of the hermaphrodite strain (28 cases) differed from those of normal type in showing a delay in the time at which atrophy of the

cortical tissue begins; this atrophy was first observed, in 2 of 7 cases examined, on day 17. This tissue had disappeared in only 1 of 4 embryos at day 18, and in only 3 of 6 embryos examined at 5 days after hatching. Birds that retain large amounts of ovarian tissue at and after hatching are presumably the ones that have been observed to possess a left ovotestis and (or) a left oviduct in adult life.

#### MISCELLANEOUS

Dr. Hollander has prepared various papers or items for publication. The titles of these communications will be found in the bibliography for this year or next year. One of these papers provided an extensive review of "Mosaic effects in domestic birds"; another study, conducted on the flock of pigeons personally maintained by Dr. Hollander, resulted in the paper, "A lethal achondroplasia in the pigeon."

Mrs. Smith has developed and published a technique for the complete removal of the parathyroid glands of pigeons. Several studies conducted in this laboratory during the past two or three years on medullary bone formation, and on factors affecting calcium and phosphorus levels in the blood, have required an extensive use of this technique. Riddle, Rauch, and Smith earlier found that the parathyroid tissue of certain pigeons (e.g., Carneaux) lies wholly external to the thyroids; in these animals, therefore, parathyroidectomy is of special interest, since it involves no injury to or reduction of thyroid tissue.

#### ENDOCRINES AND CONSTITUTION

Manuscripts describing the results of Riddle's twenty-four-year study of the relation of endocrines to constitution in doves and pigeons have been completed. Several of the more important results of that study have been indicated in Year Books of the past eighteen years. The

additional facts that have emerged under a final analysis of the data cannot be properly considered here; they are presented in one or another of the eighteen chapters which provide a full account of one of the Institution's most prolonged experimental studies. The present statement, however, will refer to one result that hitherto was unsuspected, and will in addition discuss briefly the nature and significance of the entire study.

An unusual "selection" experiment, conducted principally on twenty-four pairs of ring doves (and on their progeny), will be discussed further in later paragraphs. The final data show that at least two of these twenty-four derived dove progenies, or "races," differed from other races with respect to a sex difference in body weight. Normally, male doves are heavier than females; but the present tests led to the establishment of two races in which this condition did not exist, and also to the establishment of still other races in which this sex difference was more marked than in other races. It should be stated that these differences were not consciously sought, but were a by-product of other selection. Since various measurements were made continuously on all the races (progenies), the data thus obtained might be expected to provide information concerning the relation of endocrine status to the presence or absence of this sex difference in body weight. This expectation was fulfilled only in small measure. Good, though perhaps inadequate, evidence indicated that races which show no difference in body weight have the highest rate of heat production and therefore probably a high level of thyroid function; again, races with unusually large sex difference in body weight had unusually low rates of heat production. Less consistent evidence indicates that in races which show no sex difference in body

weight the females attain sexual maturity at a more advanced age than do the females of races which exhibit a sex difference in body weight.

The primary purpose of the study now completed was to learn whether certain of the individual differences of doves could be established as racial characteristics, and, if so, whether hormonal differences are associated with one or another of such racial differences. It would seem that facts derivable from a study of this kind should have nonnegligible implications in regard to both individual and racial differences in man. In the long and complicated task of recognizing, measuring, and evaluating human constitutional differences—as in the similar and, we believe, better-performed task concerning human origin—it seems clear that experimental animals must be expected to supply some basic principles and much indispensable information. A variety of reasons led to the acceptance of doves and pigeons as species especially suitable for one such study. For example, the degree of mongrelization present in each of these species is apparently comparable with that in the human population of an American city, and many findings relating to constitutional factors in these birds are probably applicable to man. Support for that early view has accumulated during the twenty-four years that have elapsed since the present study was started.

During the progress of this study it became evident that we were, in fact, then dealing with physiological and structural inequalities of related groups of individuals (races). It should be observed that the word "inequalities," not "differences," is used in the preceding sentence. Since physical conditions could here be virtually leveled—substantially equalized—and since social, educational, and related influences are wholly improbable in this material, it

is concluded that the highly important distinction between "inequalities" and "differences" is implicit in the results of this investigation.

Whether the segregated groups should be called "races," "breeds," "stocks," or "types" is immaterial. It is wholly probable that numerous humans carry and transmit genetic factors predisposing to the extremes of most or all of the several traits studied in doves. And the strong presumptive evidence that similar segregates are (theoretically) obtainable within *Homo sapiens* is not contradicted by any

valid evidence of which the writer is aware. The results of the present investigation thus provide direct experimental support for the view, now prevalent among anthropologists, that the products of endocrine glands do much to shape the anatomical variants with which their measurements usually deal. These results also lend support to those few anthropologists who conclude that it is not alone "under-privilege which makes the underdog." Widespread genetic inequalities of individuals and groups characterized the organisms here subjected to tests.

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## NUTRITION LABORATORY

*Boston, Massachusetts*

THORNE M. CARPENTER, *Director*

The activities of the Nutrition Laboratory during the past year have been devoted almost exclusively to investigations on war research projects under a contract of the Office of Scientific Research and Development with Harvard University. These studies are conducted in cooperation with the Harvard School of Public Health. The investigation that was started on January 1, 1943 was finished during the past year. Several other projects have been completed or are rapidly approaching completion. Three reports have been prepared for the Office of Scientific Research and Development. With the resignation of members of the staff and the almost complete absorption of the remaining staff members in the war researches, all other scientific activities have ceased. With formal conclusion of the Laboratory's work in immediate prospect, a review of its contributions during the past thirty-eight years is made part of this report.

The Nutrition Laboratory was established in 1907 with Dr. Francis G. Benedict as Director, and he continued in this capacity until 1937, when he retired. The building was completed early in 1908 and active work on construction of apparatus and the carrying out of investigations began at that time.

The primary purpose of the Laboratory was to conduct fundamental scientific investigations in vital activity with special reference to the laws governing total metabolism, heat production, heat elimination, and heat regulation. Although the undertaking was designated as the Nutrition Laboratory, the main part of its work has not been in nutrition as popularly

understood, but has consisted in fundamental studies on basal metabolism and heat production as a basis for determining the requirements of energy in nutrition to meet the needs for heat for body processes and muscular activity. Only occasionally have prescribed diets, digestibility studies, and analyses of foods been employed. Special studies on food composition have occasionally been made, such as analyses of Bengali foods, foods of the Maya, foods of the Navajo Indians, and the common everyday extra foods eaten at other times than regular meals.

From the beginning, emphasis has been laid upon exchange of information with workers in other countries. Periodic trips were made to Europe, to become acquainted with investigators in similar lines of work, to gain a more intimate knowledge of their researches, and to acquire newly developed apparatus that would be useful in investigations in the Laboratory. Information regarding experimental work in progress in the Laboratory was imparted freely to other workers, and on several trips series of lectures were given gratuitously on the latest studies in the Laboratory. Foreign workers were invited to spend the greater part of an academic year at the Nutrition Laboratory as research associates. The funds for most of these were provided by special grants from the Institution, and occasionally by grants from other organizations. Many other workers came to the Laboratory for periods of varying length to become acquainted with the various forms of apparatus and the problems on which the Laboratory was engaged. Many American investigators

also, who participated later in cooperative studies, came to the Laboratory to be trained in the apparatus and techniques.

Cooperation with other workers and other institutions and universities has had a prominent role all through the investigations of the Laboratory. In the first year of active construction of apparatus, 1908, a cooperative study on the metabolism of diabetes mellitus in man was begun with Dr. Elliott P. Joslin, of the New England Deaconess Hospital. This cooperation with him and with his colleagues was carried on almost continuously until 1943. Other cooperative investigations are mentioned below.

A major part of the activities of the Laboratory has been the development and testing of various types of apparatus for the measurement of heat production, heat elimination, respiratory exchange, and surface and internal body temperature. The earliest project was the construction of four respiration calorimeters for human subjects for special purposes, and more particularly for periods shorter than 24 hours. The comparison of direct and indirect calorimetry was an outstanding problem; it was found that the measurement of respiratory exchange in short periods gave a reliable measure of heat production, and consequently the use of calorimeters was gradually diminished. The necessity for a more sensitive type of calorimeter for measuring rapid changes in heat elimination such as might occur in studies of heat regulation led to the development of the emission respiration calorimeter for animals in 1916 and for humans in 1920. At the time of writing, with the finding that direct calorimetry is no longer necessary for the majority of problems in total metabolism, only the emission calorimeter for humans is still in functioning condition.

From the beginning the development of respiratory apparatus for measurement of very short periods was also an object of investigation. This resulted in an apparatus by which reliable results could be obtained in as short a period as one-quarter hour. This apparatus has been simplified more and more, and now devices based on the principles involved are widely used in thousands of clinics and hospitals for determination of basal metabolism of human patients. Various types of apparatus were also originated for determining the respiratory exchange of animals of various sizes and species. The standard European types of apparatus for measurement of total metabolism were obtained. For many years one of the most important phases of the work of the Laboratory was the study of the use of these apparatus—also of apparatus devised in American laboratories—and of their technical difficulties, reliability, and accuracy, in comparison with the apparatus originated in the Laboratory.

Most of the earlier respiration apparatus devised in the Laboratory were based on the closed-circuit principle. In 1922, however, a gas analysis apparatus was developed which permitted the analysis of atmospheric air and air coming from open-circuit respiration apparatus with an extraordinarily high degree of accuracy. Thereafter, more and more the open-circuit principle of measurement of respiratory exchange was applied, particularly in studies on animals of various sizes, and in studies where exact information was needed on the respiratory quotient as an index of the character of body material and the rapidity with which true basal condition was obtained, and on the effect of food on the character of the metabolism. The use of the open-circuit principle with gas analysis made possible the measurement of total metabolism of

animals with which the use of the closed-circuit system would have been impracticable.

The necessity for establishing standards of basal metabolism of normal human subjects of both sexes was early recognized, and this project constituted one of the major activities of the Laboratory. Gradually large enough numbers of adult human subjects were studied so that standards were devised based on height, weight, age, and sex instead of body surface. This accumulation of measurements also furnished material for derivation of basal metabolism standards in other ways by other workers. It is now customary for students of basal metabolism to use the Nutrition Laboratory standards as well as other standards for the estimation of the normality and abnormality of basal metabolism results. The studies on the normal basal metabolism were also extended to comprehensive series on human subjects from birth to old age, so standards are now available for all ages of both sexes of humans. Special researches were made on the conditions that may affect basal metabolism, such as position of the body, temperature, vegetarian diet, athletic activity, environment, season, fatigue, and the neutral bath. As several members of the staff either have been on the staff for a number of years or were available for periodic measurements, information has been obtained on the progressive effects of age on this factor.

In 1912, a notable study was made of the total metabolism, heat regulation, and balance of energy and of materials in a 31-day fast of a human male subject.

In 1913, an extensive program on the physiological and psychological effects of ethyl alcohol was inaugurated, and for a number of years this constituted a substantial part of the activities of the Laboratory. Even after the advent of the prohi-

bition law the study of the physiology and chemistry of alcohol in man and animals was continued in special researches.

In 1917-1918, a comprehensive investigation was made of the physiological and chemical aspects of a group of young men of the International Y. M. C. A. College in Springfield who underwent undernutrition for an extended period. This resulted in considerable information on the ability of young men to carry on the physical and mental activities of normal life on a submaintenance diet.

The finding in 1925 that the basal metabolism of Oriental women living in the United States was lower than that found for American women led to an intensive and cooperative campaign on the study of race metabolism. A special apparatus was devised, compact and easily transportable, for the determination of basal metabolism in field studies and anthropology. Workers from other laboratories were trained at the Nutrition Laboratory and subsequently carried on studies of the basal metabolism of races in various parts of the world. The studies included the blacks and browns in Jamaica, the Maya in Yucatan, women of various races in southern India, the aborigines of Australia, natives of Manchuria, types of Chinese in eastern and western China, and various races and mixtures of races in the Hawaiian Islands. The results have been brought together in a large number of publications on race metabolism and have shown clearly that some races have a definitely higher metabolism and some a lower metabolism than that of the Caucasian race.

It was early recognized that our information regarding quantitative and qualitative aspects of the factors that go to make up the total metabolism of man could be supplemented by studies of the metabolism of animals. The research on

undernutrition in man in 1917-1918 led to a study of the possibility of the subsistence of cattle on a submaintenance diet, followed by an investigation of the subsequent realimentation. In the latter part of 1918 work was begun in cooperation with Professor E. G. Ritzman, of the University of New Hampshire, on this problem in the study of the total metabolism of undernourished steers. In 1922 similar work was done with fasting steers. This cooperative effort proved most profitable and was continued until 1938. Steers, cows, horses, sheep, goats, and pigs were used in research on the basal metabolism and the effect of food ingestion on total metabolism in both qualitative and quantitative aspects, and on the effect of season, of variations among breeds, and of external environment. These researches have been supplemented by studies on surface and internal body temperature under differing environmental conditions.

Researches on the basal metabolism of a great variety of animals have been conducted, usually covering a number of years. Rats were studied at Columbia University in cooperation with Professor H. C. Sherman and Professor Grace MacLeod, and at Yale University with Professor L. B. Mendel. Studies at the New York Zoological Park on wild animals in captivity included birds from the 600-gram bittern to the 17-kilogram cassowary, and cold-blooded animals from the gopher tortoise to the 132-kilogram tortoise as well as lizards, snakes, and pythons of various weights and sizes. At the Laboratory, valuable information was gained from a research project on the woodchuck, which forms a link, so to speak, between the warm-blooded and the cold-blooded animals in that at various periods it is in a condition like that of warm-blooded ones, and during hibernation it simulates the

cold-blooded ones. The investigation concerned its total metabolism, the qualitative aspects of its metabolism, and its heat regulation during periods of normal activity, of going into hibernation, and of change from the hibernating state to the state of normal activity. The basal metabolism and heat regulation of the rabbit was extensively studied; other animals investigated there were canaries, sparrows, wild rats, frizzled fowl, and mice. The basal metabolism of the chimpanzee was studied at the Yale Anthropoid Experiment Station, Orange Park, Florida; that of the rhesus monkey, at the Department of Embryology of the Carnegie Institution, in cooperation with Dr. G. L. Streeter and Dr. C. G. Hartman; that of various races of doves and pigeons, in cooperation with Dr. O. C. Riddle at the Department of Genetics of the Institution. An investigation on the total metabolism of a 4-ton elephant was supplemented by several researches on various phases of the physiology of the elephant, using single elephants and groups of elephants.

In all these investigations on the basal metabolism and the various factors affecting it, special stress was laid on the necessity for finding the point of thermic neutrality—that is, the environmental temperature at which the metabolism was lowest—and on the complete absence of muscular activity. These two factors have not always been recognized in studies by other investigators.

The total heat production of any animal is, in general, made up from the combustion of the three groups of food components, proteins, fats, and carbohydrates. When these are burned in the body, each group produces a characteristic ratio between the volumes of carbon dioxide given off and of oxygen consumed. This ratio is called the respiratory quotient. When

the total respiratory exchange is known, and the nitrogen in the urine due to the destruction of protein is known, it is possible to compute the amounts of the three substances burned in a given period. As a contribution to our information regarding the source of the substances furnishing the fuels for combustion that make up the total heat production, a knowledge of the respiratory quotient is of the utmost importance. The development of the gas analysis apparatus in 1922 made possible a more exact determination of the respiratory quotient and of the various factors affecting it in both animals and man than had previously been feasible. The finding, early in the studies with the simple sugars, dextrose, levulose, and galactose, into which the carbohydrates of the diet are for the most part resolved in digestion and absorption, that the response of the respiratory quotient after their ingestion by man differed widely, led to an intensive study of the factors that might cause these variations. The finding by other workers that the response of the respiratory quotient in rats seems to differ widely from that in man led to a

series of studies by means of the open-circuit apparatus and gas analysis on the variations in the changes in the respiratory quotient after the ingestion of these three sugars by various species of animals, including the mouse, rat, canary, monkey, goat, and cat. The results show that there are wide variations in the metabolism of carbohydrates with these three sugars, both qualitatively and quantitatively. Although animals in general burn carbohydrates, fats, and proteins as does man, the manner in which these processes are carried out, both qualitatively and quantitatively, differs widely in the different species, so that it is not safe to transfer the results from one species to another without some qualifications.

The results of the various investigations of the Laboratory are presented in 35 monographs published by the Institution and in 414 articles that have appeared in scientific journals.

Since the beginning of 1941 the purely scientific activities of the Laboratory have gradually lessened because of the participation of the members of the staff in war researches.

#### STAFF NOTES

Mr. Robert C. Lee, a member of the staff since January 1929, resigned August 31, 1944. Miss Elsie A. Wilson, since September 1913 a member of the staff, resigned November 30, 1944. Mr. George Lee, a member of the staff since September 1929, resigned January 31, 1945. Mr. George Lee was an expert gas analyst and photographer. Mr. Robert C. Lee conducted a large amount of experimental work and in recent years contributed substantially to the published output of the Laboratory. Miss Wilson has been of inestimable value as secretary and editor and has aided very materially in the preparation of many manuscripts for publication.

Miss Evelyn Barenberg was employed as secretary from November 20, 1944 to June 1, 1945.

The entire time of Mr. Robert C. Lee and Mr. George Lee until they resigned was employed in the war activities. Mr. V. C. Coropatchinsky has been engaged exclusively the entire year in the construction of newly developed apparatus for the war researches. About a month of Miss Wilson's time was spent on the preparation of reports on the war activities. On March 23, 1945, Dr. Carpenter gave his annual lecture on basal metabolism before students of the Harvard Medical School.

## LITERARY WORK

The following articles have been completed for publication in scientific journals:

"The basal metabolic rates of South American Indians," by Elsie A. Wilson. (Accepted for publication in the *Handbook on the Indians of South America*.)

"The respiratory quotient and blood pyruvate and lactate responses after oral ingestion of glucose and fructose in diabetes mellitus with and without insulin," by Howard F. Root, Elmer Stotz, and Thorne M. Carpenter. (Accepted for pub-

lication in the *American Journal of Medical Sciences*.)

"The effects of the dietary supply of carbohydrate upon the response of the human respiratory quotient after glucose administration," by Howard F. Root and Thorne M. Carpenter. (Accepted for publication in the *Journal of Nutrition*.)

"The respiratory quotients (R.Q.) of diabetic subjects after meals," by Howard F. Root and Thorne M. Carpenter.

## PUBLICATIONS

(1) *A new method for studying breathing with observations upon normal and abnormal subjects.* Leslie Silverman, Robert C. Lee, and Cecil K. Drinker with the cooperation of Francis M. Rackemann. *Jour. Clin. Investig.*, vol. 23, pp. 907-913 (1944).

A new pneumotachographic device is described for making a graphic record of the velocity of air movement during inspiration and expiration. The inspiratory and expiratory air currents cause the deflections of fine wires, deflections that are recorded photographically by a moving paper camera. Typical illustrations of the resulting curves are presented, showing the results on one normal individual and on five patients with respiratory difficulties. The total minute volume and the instantaneous air flow can be obtained from the records made by the instrument.

(2) *The effects of glucose, fructose, and galactose on the respiratory exchange of the goat.* Ernest G. Ritzman and Thorne M. Carpenter. *Jour. Nutrition*, vol. 28, pp. 71-79 (1944).

The respiratory exchanges of four male and five female adult goats were determined 40 hours after withdrawal from food (1) under basal conditions and (2) in eight successive  $\frac{1}{2}$ -hour periods after the administration by stomach tube of 250 ml. of water at  $37^{\circ}-38^{\circ}$  C., or of 25 gm. of glucose, fructose, or galac-

tose dissolved in 125 ml. of water and an additional 125 ml. of water for rinsing. Water produced a slight but somewhat delayed increase in the R.Q. Fructose caused the greatest increase in the R.Q. and the greatest increase in the metabolism of carbohydrates. Glucose was next in these effects, and galactose had the least effects. Qualitatively these results much resemble those found with man with these sugars. There was evidence of a slight amount of fermentation after the ingestion of galactose and of fructose by the goats.

(3) *The effects of sugars on the respiratory exchange of cats.* Thorne M. Carpenter. *Jour. Nutrition*, vol. 28, pp. 315-323 (1944).

The respiratory exchange was measured in successive  $\frac{1}{2}$ -hour periods for 4 hours with five cats in the basal state, after ingestion of 75 ml. of water, after ingestion of 10 gm. of glucose, fructose, galactose, sucrose, maltose, or lactose, and after ingestion of a combination of 5 gm. each of glucose and fructose or of glucose and galactose. The values of the basal R.Q. were uniform, for the most part, and did not show a marked tendency to change during the eight  $\frac{1}{2}$ -hour periods of measurement. The ingestion of water resulted in a rise in R.Q. with one cat for the entire 4 hours, but with the other cats only in the first  $\frac{1}{2}$ -hour period. Glucose caused the great-

est rise in R.Q., and the peak occurred in the sixth and seventh  $\frac{1}{2}$ -hour periods. All the other sugars, disaccharides as well as monosaccharides, caused definite rises in the R.Q. On the assumption that in the control experiments with water only fat and protein were metabolized and that in the experiments with the sugars the protein metabolism of a given cat was the same as its average protein metabolism in the experiments with water, it was calculated that the metabolism of carbohydrates was highest after glucose and lower after galactose and fructose in the order named. The cats were able to metabolize the disaccharides nearly as well as would be expected, in view of their constituent monosaccharides formed by hydrolysis. When combinations of hexoses equivalent to 10 gm. of sucrose or lactose were ingested, the resultant metabolism of carbohydrates was greater than would be expected from the sum of the amounts metabolized after ingestion of the respective hexoses given separately. Cats resemble men in the metabolism of the monosaccharides in that they show increases in R.Q. and in carbohydrate metabolism after ingestion of these sugars, but they differ from men in that the peak does not occur so promptly and, qualitatively, the order of magnitude of the effect is not the same.

(4) *Basal metabolism from the standpoint of racial anthropology.* Elsie A. Wilson. Amer. Jour. Phys. Anthropol., n. s., vol. 3, pp. 1-19 (1945).

From many hundreds of metabolism measurements on normal men, women, and children of the white population of the United States, average values or normal standards of basal metabolism have been derived showing the energy needs of normal people. These normal standards vary, depending on age, weight, height, and sex. When other racial groups besides North American whites were studied, for example Chinese students in the United States, Maya Indians of Yucatan, and various races in South America, India, Australia, and other parts of the world, it was discovered that their basal energy needs were

often higher or lower than the normal standards for the white population in the United States. Many investigators believe that these differences are ascribable to race and that this factor must be considered in addition to age, weight, height, and sex. Other investigators claim that race plays no role, but that the deviations from the normal standards for North American whites can be explained by differences in nutritive condition, climate, and other factors.

This review of the literature on the basal metabolism of different human races discusses these conflicting opinions and points out the many different conditions entering into the measurements that make it difficult to decide whether race itself is or is not a factor in basal metabolism. Among these are differences in physical activity and degree of muscular relaxation, differences in body size and body configuration, differences in diet, differences in climate and seasons of the year, and differences in anthropological and constitutional types. Another complication is that the normal standards of basal metabolism are commonly related to body size, particularly the surface area of the body, and the formula for calculating this area worked out for whites may not necessarily apply to all races. Moreover, different methods have been used in measuring the basal metabolism of the various races studied, instead of one and the same method.

A tabular summary is given of the results of those racial investigations in which basal metabolic rates above the normal American standards have been found. Another summary is given of the results of those investigations in which minus values of more than 10 per cent have been found, and still a third summary of the results of racial studies made between 1940 and 1942.

One of the striking findings is that most of the groups having basal energy needs distinctly higher than the standards for normal whites belong to the Mongolian race. These groups include Eskimos and American Indians.

From this survey it is evident that so many different factors may play concurrent roles in

affecting the basal metabolism that it is impossible at the present time to say whether the different basal metabolic levels noted for the various races thus far studied are reflections of a racial characteristic or are the results of a combination of some or all of the factors mentioned. The desirability of further studies on different races with the use of the same technique of measurement in all cases is urged, to rule out the factor of difference in technique. The suggestion is made that sufficient measurements be made to establish a normal standard for each individual race, based on measurements of normal individuals of the race in their

native country. When such standards have been established for many different races, a comparison of these with the present-day American and European standards should throw more light on the role played by race in basal metabolism.

(5) *The respiratory quotient and blood pyruvate and lactate after ingestion of glucose or fructose by diabetic patients.* Thorne M. Carpenter, Howard F. Root, and Elmer Stotz. *Federation Proc.*, vol. 4, pp. 152-153 (1945).

A preliminary communication of results to be published in full subsequently.

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— See RITZMAN, ERNEST G.

DRINKER, CECIL K. See SILVERMAN, LESLIE.

LEE, ROBERT C. See SILVERMAN, LESLIE.

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## SPECIAL PROJECTS: BIOLOGICAL SCIENCES

T. H. MORGAN, ALFRED H. STURTEVANT, and LILIAN V. MORGAN, California Institute of Technology, Pasadena, California. *Maintenance of a Drosophila stock center, in connection with investigations on the constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15 to 43.)

The results of the work of A. H. Sturtevant on chromosome types of *Drosophila melanogaster* are reported as follows:

The fourth chromosome of *Drosophila melanogaster* is usually given as 0.2 units long. This value is evidently too high; there is probably less than 0.05 per cent crossing over between any of the known loci. When linkage experiments are carried out, it often happens that the design is such that nondisjunction will simulate

that are of value in studies on this chromosome: *gvl sv<sup>n</sup>*, *ci sv<sup>n</sup>*, and *gvl sv<sup>n</sup> ey<sup>R</sup>*. It should be added that the two latter are inconvenient to work with, owing to an unexplained high incidence of male sterility.

The construction of a crossing-over map has encountered an unexpected difficulty, namely, that the data indicate that some of the crossovers obtained have resulted from double crossing over. This is so unexpected, for a section showing so little total crossing over, that the result must be thoroughly checked before any confidence can be placed in it. All that can be said at present is that most of the observed crossing over occurs in an interval lying between the loci of *gvl* and *ci* on the one hand, and those of *sv* and *ey* on the other, but that occasional crossovers also occur between the members of each of these two pairs of loci.

These studies are being continued and the preference properties of the crossover chromosomes are also being determined.

Dr. K. W. Cooper, of Princeton University, has carried out studies, partly in this laboratory, on the effects of inversions on crossing over and chromosome disjunction. Some of the data are in press, and other experiments are still in progress. These studies, like those on preference properties of fourth chromosomes, are aimed at throwing light on the mechanics of chromosome behavior—a field that has recently been somewhat neglected by geneticists, but in which the material available in *Drosophila melanogaster* makes it

TABLE 1

CROSSING OVER IN DIPLO-IV TRIPLOID FEMALES OF *DROSOPHILA MELANOGASTER*

Loci	Total no. flies	No. crossovers	Percentage
<i>gvl ey</i> .....	1513	40	2.6
<i>gvl sv</i> .....	680	22	3.2
<i>ci ey</i> .....	965	15	1.6
<i>ci sv</i> .....	158	7	4.4

crossing over, and this confusion has probably led to the value usually given.

Recent experiments have, however, shown that crossing over in this chromosome is greatly increased in triploid females, as shown in table 1. Most triploid strains carry only two fourth chromosomes, and the data were derived from such females. Crossing over in triplo-IV triploids is more difficult to analyze, and, therefore, few counts have been made from them; a few crossovers were, however, present in the small numbers obtained.

These experiments have resulted in the production of three new multiple stocks,

possible to carry out critical tests with a precision and efficiency nowhere else attainable.

The fourth-chromosome recessive character sparkling (*spa*), described in the report of 1942-1943, has been further studied by L. V. Morgan in experiments designed to test the correlation between the manifestation of *spa* and relative amounts of heterochromatin and euchromatin.

*Spa* is manifested primarily by roughness and brightness of the eye and by other conditions such as shape and convexity. Roughness seems to be in part due to irregularity in the rows of ommatidia, which sometimes vary in size.

In order to facilitate comparison of different degrees of *spa*, an arbitrary scale of 7 grades was chosen. An eye of grade 6 is exceedingly rough, has no fleck, and is often bulging, round, and small. In grade 1 roughness is very slight, sometimes not involving all of the eye, sometimes discernible only in certain positions in relation to the source of light; it scarcely differs from grade 0 or "smooth." Grade 2 is evidently *spa*. When feasible, one parent in the mating was heterozygous for *spa* and for its wild-type allelomorph in a chromosome marked by the dominant wing mutant *cubitus interruptus* dominant (*ci<sup>D</sup>*). Thus homozygous *spa* eyes could be compared in the same conditions directly with wild-type eyes, which sometimes are of a granular texture rather than entirely smooth. As there is no actual division between grades, the classification of borderline cases varies. For this reason and because *spa* is probably sensitive to genetic modifiers, the controls were present whenever possible in the same culture in which *spa* was rated, or sibs were used as *P<sub>1</sub>* flies.

Temperature affects the grade of *spa*, which is enhanced when the flies are raised

at 17-19° C., the range chosen for the experiments. When first found, *spa* was raised at room temperature. In extracted homozygous flies *spa* was easily seen in females, but did not show in males. Raised at 19°, females were of higher grades and males showed low grades of *spa*.

Females have been found to be of higher grades than their brothers in every experiment in which the females were XX and the males were XY (possibly excepting flies carrying a deficiency for chromosome 2). But females carrying normal X's and also a Y chromosome do not show *spa* as observed in the regular class of attached-X females which are XXY. Their exceptional XXO sisters are *spa* and of higher grades than are the regular XY males. Sons of XXO females which are XO males show the highest grades of *spa* (6 and 5), exceeding even the grades of the few XXO females found in the same stocks of flies. These observations show a lowering of the grade of *spa* in the presence of a Y chromosome.

A correlation has also been found between the presence of differing amounts of heterochromatin in the X and the expression of *spa*. The X deficient for X heterochromatin and for the locus of bobbed found by Gershenson (Df G) was used (symbol X<sup>-</sup>). The grades of offspring of females heterozygous for X and X<sup>-</sup> mated to XY males are recorded in table 2 under A. Both females and males deficient in X heterochromatin are of higher grades than are the corresponding flies carrying the normal X's.

In another class of females (X-X-Y) which carried two deficient X's and a Y chromosome, there were smooth-eyed flies and flies of grade 1 (table 2 under B). This indicates that two X deficiencies have an effect on *spa* which is opposite to and nearly balances the effect of Y. An extra

$Y$  in a deficient male ( $X^cYY$ ) suppresses  $spa$  as seen in the males of the class that had received a  $Y$  from each parent. The result is similar to the suppression of  $spa$  by  $Y$  in  $XXY$  and  $XY$  as compared with  $XXO$  and  $XO$ .

There are other examples of effects on  $spa$  of different amounts of heterochromatin in the  $X$  and the  $Y$  chromosomes. An  $X$  chromosome known as bobbed lethal ( $bb^l$ ) is probably deficient for the locus

In  $X^cX^cY$  females that carried  $Df D$ ,  $spa$  was less evident even than in corresponding  $Df G$  females, which are of low grade. When a normal  $X$  is present in place of one deficient  $X$ , the females ( $X^cXY$ ) carrying either deficiency do not show  $spa$ , though  $X^cX$  females are of high grades.

When a deficient  $Y$ , known as  $Y$  sterile ( $Y^{st}$ ), which is probably the long arm of  $Y$ , is combined with  $bb^l$  deficiency in  $X^cX^cY^{st}$  females,  $spa$  is of a high order. Another  $Y$ , "Y bobbed deficiency" ( $Y^{bb^-}$ ), is deficient for  $bb$  and for about one-third of the short arm of  $Y$ , but males carrying it are fertile. It has less effect on the suppression of  $spa$  than has a normal  $Y$ . In attached- $X$  females that are  $XXY^{bb^-}$ ,  $spa$  is evident, and  $XY^{bb^-}$  males are even more  $spa$  than the females, but less  $spa$  than are  $XO$  males.

It was found further that duplication of  $X$  heterochromatin has an effect opposite to that of a deficiency and in the direction of the effect of  $Y$ . Flies carrying a largely heterochromatic fragment of  $X$ ,  $Dp(1;f)101$ , in addition to the normal complement of  $X$ , produced smooth duplication males ( $XX^{Dp}Y$ ) and  $XY$  males which were slightly  $spa$ ; and 84 per cent of  $XX$  females were of grades 4 and 3, while 82 per cent of the females carrying the duplication ( $XXX^{Dp}$ ) were of the lower grades 2 and 1, although a common effect of duplication is slight roughening of the eyes.

Another deficiency for heterochromatin,  $Df(2)M-S10$ , was tested. It is a deficiency for a heterochromatic region of the right arm of chromosome 2, which produces a dominant mutant effect ( $M$ ) and is lethal when homozygous. The Minute offspring ( $M$ ) of flies heterozygous for the deficiency are conspicuously more  $spa$  than are their normal sibs. This is true especially of the

TABLE 2

NUMBER OF FLIES OF DIFFERENT GRADES OF SPA  
( $X^c$  stands for deficient  $X$  of Gershenson)

	0	1	2	3	4	5	6
A. GRADES OF SPA IN OFFSPRING OF $X^cX$ BY $XY$ WITH AND WITHOUT $X^c$							
$X^cX$ .....	..	..	..	..	16	38	29
$X^cY$ .....	..	49	55	..	..	..	..
$XX$ .....	..	..	13	33	52	14	3
$XY$ .....	70	8	..	..	..	..	..
B. GRADES OF SPA IN OFFSPRING OF $X^cX^cY$ BY $XY$							
$X^cX^cY$ ....	42	48	2	.	..	..	.
$X^cY$ .....	..	2	33	43	13	3	..
$X^cYY$ ....	64	..	..	..	..	..	..

of  $bb$ , and an  $X$  chromosome found by Dobzhansky ( $Df D$ ) is deficient for the locus of  $bb$  and for a heterochromatic region. Each of these showed an effect on  $spa$  in  $XX^c$  females and in  $X^cY$  males. The females showed  $spa$  to a high degree and the males were only slightly  $spa$ . The grades were not rated by the scale, but in comparisons made at long intervals of stocks of the three deficiencies,  $Df G$  appeared to be the most effective in enhancing  $spa$ , and  $bb^l$  the least effective. The stocks were unrelated, so there were no checks on modifiers except  $ci^D$ , which was present in some instances.

males, which run into the highest grades as do the females. Of the not-*M* offspring, lower in grade, the males are less *spa* than the females.

The effect on the fourth-chromosome character *spa* of the presence of different amounts of heterochromatin is in agreement with the effect of heterochromatin

on variegations in other chromosomes which has been described by Schultz. The experiments with *spa* give consistent results in the sense that when heterochromatin of X or of Y is increased, the manifestation of *spa* is diminished, and when heterochromatin of X, Y, or 2R is decreased, *spa* is enhanced.

H. C. SHERMAN, Columbia University, New York, New York. *Research on influence of nutrition upon the chemical composition of the normal body.* (For previous reports on this and directly preceding researches, see Year Books Nos. 32 to 41 and 43.)

The fact that a normal bodily chemistry may yet be improved by a more scientific adjustment of the nutritional intake has opened a far-reaching field of research into the effects of food upon life processes and life histories. The present research deals, as has been briefly explained in previous reports, with the effects of such nutritional improvements. These are induced in some cases by adjustments of the quantitative proportions of natural foods in the diet, and in other cases by enrichment of the diet with chemically individual nutrients.

By the former method we found that a diet already adequate in the sense that it supports normal growth, health, and life histories through successive generations can yet be so improved as to better the average status in each part of the life cycle.

Our subsequent experiments with individual nutrients indicate that calcium, vitamin A, riboflavin, and protein each plays a part in the enhancement of an already normal status of nutritional well-being, with resultant improvement in the plane of positive health, and the average length of life. Rats are the experimental animals used in this work because, in all aspects of the nutritional chemistry with which we are here concerned, their processes run strikingly parallel with those of human

beings, and enough faster so that they complete their normal life cycles in about one-thirtieth of the time. Rat families in our laboratory colony are now thriving in the sixtieth generation on our basal diet A, which in the sense here described is already adequate, yet capable of improvement at more than one point, as doubtless are the dietaries on which a large proportion of people are living.

Hence such study of the influence of food—upon the bodily chemistry and resultant nutritional well-being and life history—holds much of significance for the correlation of chemical composition and biological function, and for important human implications.

Our experiments with calcium as the sole variable factor were summarized briefly in our report of 1940-1941 and more fully in the journal articles there recorded (Year Book No. 40, pp. 287-288).

At that time and in the following year (Year Book No. 41, pp. 245-246) progress reports were made upon our analogous experiments with vitamin A, the data of some of which are now being prepared for journal publication. These experiments are showing that a moderate surplus of vitamin A in the daily diet is even more potent than previously supposed in the support of bodily reserves of this nutrient

at all ages up to at least middle life. Moreover, in families thus fed through successive generations, growth is stabilized and the period of full adult vigor appears, in the experiments thus far completed, to have been extended. We hope to carry these experiments into larger numbers at the higher levels of nutritional intake and the more advanced ages.

Our experimental studies of the influence upon body composition of different liberal levels of nutritional intake of riboflavin, both as sole variable and in conjunction with different levels of food protein, are being continued. As was noted in last year's report, our work with riboflavin as sole variable yields a general picture of a riboflavin content of body tissue which varies with the nutritional intake at relatively low levels, whereas at higher levels of intake the concentration of riboflavin in the tissue reaches a "plateau" and thereafter remains essentially constant with further increase of riboflavin intake. This plateau level of riboflavin content of body appears, however, to be influenced by the protein content of the diet, consistently with the theory that riboflavin in body tissues exists largely in combination with protein. Thus in a series of five comparisons of the body concentrations of riboflavin and total nitrogenous compounds (quantitatively an essential measure of protein content) in rats that had been fed diets of the same liberal riboflavin content but with 12 per cent and 32 per cent, respectively, of protein, it was found that in every case the animal receiving food of higher protein content showed a higher body content of both protein and riboflavin. The average results were: in animals from diet with 12 per

cent protein, 5.70 micrograms of riboflavin per gram, and 16.95 per cent of protein in the body; and in animals from diet with 32 per cent protein, 6.63 micrograms of riboflavin, and 18.42 per cent of body protein. Such differences, of the order of one-tenth, in the amounts of these active factors of the life process in the body tissues clearly suggest that science is here developing a previously unappreciated potentiality for the modification of life processes and thus of life histories through nutritionally guided use of food. The quantitative investigation of these relationships is complicated by the fact that the difference of nutritional intake influences the amount of fatty and fatlike substances formed and retained in the body. This is consistent with the oxidation-enzyme nature of the riboflavin-protein compound. Thus the situation deserves fuller experimental study, both as to its scope from the standpoint of systematically varied levels of the active factors fed and as to the extension of such feeding experiments to cover longer segments of the life histories. For such experiments the animals of our laboratory-bred colony, having known nutritional backgrounds for many generations, offer special advantages for conclusiveness of interpretation in the direct comparison of diets and also for the solution of the problem of how far so-called adaptation to suboptimal food supply is a factor in responsiveness to better feeding.

The generous and efficient service of those who have collaborated in the work here reported, whether as research assistants or as volunteers, is gratefully acknowledged.



## DIVISION OF HISTORICAL RESEARCH

*Cambridge, Massachusetts*

A. V. KIDDER, *Chairman*

Now that the war is over, several members of the staff who have been serving in the armed services or in other forms of war work are expected soon to return, and it is hoped that in the near future some at least of the interrupted activities of the Division may be resumed. Indeed, during the past year it has been possible to undertake a limited amount of archaeological and ethnological field work. Most staff members not in service, however, have devoted themselves to the writing of reports. As a result, the Division's investigations have been brought nearer to the stage of definitive publication than at any previous time.

Dr. Leo F. Stock retired July 31, 1945, after thirty-five years of service with the Department and Division of Historical Research. A member of the group of distinguished scholars brought to the Department by Dr. J. Franklin Jameson, Dr. Stock has centered his research on the debates in the British Parliament regarding North America. His five volumes on this subject not only throw much factual light on events of the period treated, but also make clear the slow development of democratic processes in dealing with colonial possessions. They form a necessary introduction to the legislative history of the United States after its independence. A former president of the American Catholic Historical Association, Dr. Stock has been a valued agent of liaison between the Institution and the very effective Catholic historical organizations and institutions.

With great regret we record the passing of two persons formerly connected with the Division, Ann Axtell Morris and George Clapp Vaillant.

Mrs. Morris, who possessed great abilities as a writer and an artist, was entrusted by her husband, Earl H. Morris, with the copying of the extremely important frescoes discovered by him during the excavation of the Temple of the Warriors at Chichen Itza, and was co-author of the monograph on that building. In later years she assisted Dr. Morris on his many expeditions in Arizona and New Mexico, making a specialty of the recording and study of pictographs. Her two books, *Digging in the Southwest* and *Digging in Yucatan*, which have had a large sale that still continues, have done much to acquaint the public with the methods and aims of archaeology.

Dr. Vaillant, formerly with the American Museum of Natural History and at the time of his death Director of the Museum of the University of Pennsylvania, was a member of Dr. Morley's staff at Chichen Itza in 1926. During that season he excavated the Temple of the Phalli and elsewhere, made stratigraphic studies which laid the foundation for subsequent ceramic research in Yucatan by H. B. Roberts and G. W. Brainerd. Dr. Vaillant's work for the American Museum on the early cultures of Mexico was a brilliant scientific achievement, and, like Mrs. Morris' books, his *Aztecs of Mexico* has done much to promote an intelligent interest in archaeology. Throughout his career he kept closely in touch with the Division's work, giving freely of his time to visit our excavations and advise with us as to problems of mutual interest.

## ACTIVITIES, 1944-1945

Major H. E. D. Pollock, after three years with the photographic division of the Air Corps in North Africa and Italy, returned late in 1944 for duty in Washington, and has recently been accorded inactive status. He will resume his studies of Maya architecture in the autumn of 1945. Mr. Gustav Strømsvik enlisted in 1943 in the Royal Norwegian Navy. He served on the North Atlantic convoys, took part in the invasion of Normandy, and, since the landings there, has held an administrative position at Norwegian headquarters in Edinburgh. He has recently been discharged. Mr. Karl Ruppert, volunteer in the American Field Service, was with the British Army during the Burma campaign and later in Italy. In the spring of 1945 his unit was transferred to northern Europe, where it was engaged until the end of hostilities in the evacuation of wounded and in helping to clear captured concentration camps. He has now resumed his position with the Division. Dr. G. W. Brainerd, who holds the rank of lieutenant in the Naval Reserve, is attached to the Special Devices Division of the Office of Research and Invention. His duties have taken him to India, Ceylon, and China. Miss Eleanor W. Ritchie, secretary of the Division, is a lieutenant (j.g.) in the Naval Reserve, on duty in Washington.

In civilian capacities, several members have taken part in the war effort. Mr. E. M. Shook is in charge of the large quinine plantation of El Porvenir in Guatemala. In the course of this work he has been able, as in past years, to make valuable observations on sites in a region hitherto very little known archaeologically and to obtain photographs of monuments and of objects in private collections. Dr. A. M. Halpern has continued as director of the language program in the Civil

Affairs Training School at the University of Chicago. Dr. R. S. Chamberlain, senior cultural assistant in the United States Embassy in Guatemala, has had opportunity, during his four years at that post, to foster the close international intellectual relations which, we believe, have been a not unimportant by-product of the Division's more than three decades of activity in Mexico and Central America. He expects to resume his historical studies in the near future. Mr. F. B. Richardson, in 1944 legal attaché at the Embassy in Ecuador, attended the conference at San Francisco as adviser on Latin American affairs.

Dr. S. G. Morley spent the winter in Yucatan, continuing his research on the Maya hieroglyphs. He has been in constant touch with Sr. Alfredo Barrera Vazquez, whose translation and correlation of variant historical and ceremonial Maya texts—the so-called Books of Chilam Balam—were carried on in 1943-1944 under a grant from the Rockefeller Foundation administered, at the Foundation's request, by Carnegie Institution. Mr. R. E. Smith continues in charge of the Division's office in Guatemala City. During the past winter he was informed that road work at Coban in Alta Verapaz had exposed a prehistoric midden. This he excavated, recovering a large collection of clay figurines and pottery fragments, many of the latter of a very beautiful incised ware of which only a few pieces had previously been known. Mr. Smith has also devoted much time to the installation of the archaeological collections in the Guatemala National Museum, which, under the directorship of Sr. Flavio Rodas, is being transferred to new and larger quarters. As chairman of the advisory committee on the museum, he has been assisted by

Sr. Antonio Tejeda, artist of the Division, and Sr. Antonio Goubaud.

Sr. Tejeda continues to produce meticulously accurate and beautiful paintings of Maya pottery. Although only a relatively small proportion of these can at present be used as illustrations in the Division's publications, it has been our policy to have such reproductions made of all important pieces from our own excavations and of those in museums and in private hands. The archive thus being built up will be of very great value to students who cannot see the material itself. It also serves as insurance against loss of the originals through dispersal of private collections or, in the case of museums, through destruction by earthquake, an ever present danger in the Central American republics. This year Sr. Tejeda has been working on Mr. Smith's Alta Verapaz pottery; on pieces in the Dieseldorff collection, now the property of the National Museum; and on vessels recovered by Mr. S. H. Boggs in El Salvador.

Sr. Tejeda's younger brother, Cesar, first employed in 1942 as assistant to Mr. Shook at Kaminaljuyu, developed great ability in mending and restoring pottery. During his work as preparator and in the field with Mr. Shook and Mr. A. L. Smith, he showed outstanding promise as an archaeologist. When this was brought to the attention of the authorities, he was granted a government fellowship for attendance at the Escuela Nacional de Antropología in Mexico City, where he has now matriculated. A fellowship was also given to Sr. Juan de Dios Rosales, for several years assistant to the late Dr. Manuel Andrade and to Drs. Redfield and Tax in their respective linguistic and ethnological investigations and, more recently, to Sr. Goubaud in the food survey. Such field experience as the Division has been able

to give Srs. Tejeda and Rosales and such aid in acquiring academic training as it has been able to procure for them and for Srs. Alfonso Villa and Antonio Goubaud—largely through the generous and ready cooperation of the Rockefeller Foundation—is believed to be a most valuable contribution to the development of anthropology in Latin America, for although North American students can accomplish a certain amount of useful research, the major work must eventually be done by natives of the countries themselves, as it now is in Mexico by the able group headed by Dr. Alfonso Caso.

During the past winter Mr. A. L. Smith and Sr. Cesar Tejeda made a survey of sites in the northwestern Guatemala highlands that are thought to date from late prehistoric times. Srs. Goubaud and Rosales, in the early months of 1945, completed the collection of data regarding food habits and food consumption of the Guatemala Indians and Ladinos. Dr. Kirk Bryan, professor of geology at Harvard University, spent two weeks in Guatemala studying physiographic conditions bearing upon the antiquity of human occupancy of that country. Reports on these investigations and on the ethnological work are appended. The Chairman was in Guatemala during January and February for consultation with government authorities as to future undertakings. He also had opportunity to work in the Division office on archaeological collections made in former years. Temporarily unsettled political conditions prevented his visiting Mr. S. H. Boggs' excavations at Tazumal in eastern El Salvador, which are being carried on by the Salvadorean government, and for which Carnegie Institution has provided modest financial aid for the prosecution of certain stratigraphic studies. The Chairman later went to Boulder,

Colorado, to confer with Drs. E. H. Morris and Anna O. Shepard regarding their work on Southwestern archaeology and ceramic technology; and to Albuquerque, New Mexico, to confer with Dr. F. V. Scholes. In California, he studied collections at Los Angeles and Berkeley.

At Cambridge, Mr. J. E. S. Thompson has begun the preparation of a comprehensive monograph on the Maya hieroglyphic writing. A report on certain aspects of this study appears below. Mr. Thompson has been awarded the Rivers Memorial Medal by Cambridge University for his contributions to Maya research. Miss Tatiana Proskouriakoff has begun a detailed analysis of dated Maya sculptures. This will not only lay a foundation for studies of other aspects of Maya art, but provide more reliable stylistic criteria than have hitherto been available for the dating of the many monuments which bear either no dates or illegible ones. Mrs. W. H. Harrison, in addition to her manifold duties as editor of the Division, has been compiling a dictionary of terms applicable to Middle American archaeology. This should serve to standardize usage and clarify nomenclature. Her report on publications also appears below, as do those of Dr. L. F. Stock on his work in United States history and of Dr. George Sarton on the history of science. The report on Kaminaljuyu by the Chairman, Dr. J. D. Jennings, and Mr. Shook has been finished and is now in press. In the field of Maya history, Dr. Scholes and Mr. R. L. Roys have continued the writing of their report on the Acalan-Tixchel area. Dr. Scholes and Miss Eleanor B. Adams, who now make their headquarters at Albuquerque, have been provided with quarters and given every facility for the prosecution of their work by the University of New Mexico.

#### GUATEMALA HIGHLANDS PROJECT

A. L. SMITH

During the winter of 1944-1945, Mr. A. L. Smith, assisted by Sr. Cesar Tejeda, spent four months in archaeological reconnaissance in the departments of Huehuetenango and El Quiche. The purpose of the work was to obtain as much information as possible, without intensive excavation, as to both hilltop and valley sites with a view to selecting representative examples of each type for future excavation. All sites were mapped, architectural details were recorded by drawings and photographs, and samples of pottery were recovered from inside or below constructions as well as from the surface. Special effort was made to locate refuse dumps.

The trip was made in the Institution's station wagon, and local labor was employed. The hiring of workmen was greatly facilitated by the cooperation of the Minister of Public Education, the governors of departments, and the mayors of the towns and villages visited. Seventeen sites were examined, some large and some small, all within fairly easy access of a main highway.

Huehuetenango, capital of the Department of Huehuetenango, was the first base used. In this region seven sites were investigated: Zaculeu, Cambote, Chicol, Piol, Xetenan, Cucal, and Pucal. Of these, Zaculeu, a fortified site surrounded by barrancas on three sides, proved to be by far the largest and most interesting. It lies about 4 km. northeast of Huehuetenango. Considerable excavation has been carried on here in the past, the Guatemalan government in 1927 having excavated and partially restored the principal mound, a large pyramid surmounted by a temple. About ten days were spent at Zaculeu in recording materials for restored drawings of several buildings and a ball court. A

large collection of potsherds was also made. Cambote, directly south of Zaculeu and in plain view therefrom, rests on a tongue of land but is not so well protected as Zaculeu. Very little masonry was showing here, and there was no ball court. Chicol, Piol, and Xetenan are all small hilltop sites practically surrounded by barrancas. All three have ball courts. Cucal is a small valley site without a ball court. At Pucal, a small hilltop site near Cucal, only one mound remains, but there is evidence that there were several others which had been leveled for agricultural purposes, the stones being used in the building of modern fences.

The next base of operations was the village of Aguacatan, about 26 km. east of Huehuetenango in the Department of Huehuetenango, where a month was spent investigating Huitchun, Chalchitan, Xolchun, and Chichoche. Huitchun, sometimes called Chichun, rests on a low hill just west of the village. It is a small group surrounding a court and has a ball court. Chalchitan, one of the largest sites visited, and the one to which most of the month's work was devoted, lies in the valley just east of the village. Unfortunately a great many of the mounds had been dug into by treasure hunters, causing much damage to inner constructions. There is still much left, however. One of the two ball courts was excavated and found to cover an earlier ball court, within which there was evidence of still earlier construction. Two nicely carved stone heads, one of a serpent and the other of a jaguar, were recovered from high up in the center of the playing walls of the earlier ball court. A tomb with a corbeled vault was discovered in one of the largest mounds. This had been looted years ago. Probably the most interesting find was a building showing six distinct architectural phases, the most instructive of which were a platform with

four round columns, one off each corner, and a later construction of four walls with stepped tops. There is much pottery of all periods at Chalchitan. Xolchun, east of Chalchitan, is a good-sized hilltop site. Its main features are a well preserved ball court, terracing, block masonry, and a type of late pottery with white geometric design on a red slip. Chichoche is a small group of mounds in sight of Xolchun across the barranca to the southeast.

Sacapulas, a village in the Department of El Quiche about 37 km. east of Aguacatan, was the last place used as a base. From here the ruins of Chutix Tiox, Chutinamit, Pacot, Xolchun, Rio Blanco, and Xecataloj were studied. The best preserved of these is Chutix Tiox, a hilltop site extremely well protected against attack, its only entrance being blocked by a wall. The main group is on a high terrace with stairways on all sides. An interesting feature is a stucco jaguar in a crouching position at the base of one of the several platforms. It was possible to take measurements of almost all the buildings. Chutix Tiox is similar to Xolchun in that it has the same kind of ball court, a great deal of terracing, and the same white-on-red pottery. Chutinamit, just outside Sacapulas, is another well protected hilltop site, almost completely surrounded by barrancas. Its only entrance, on a narrow neck of land to the north, was protected by three parallel walls stretching from barranca to barranca. Pacot, also almost inaccessible, is small, but the buildings are well preserved. Xolchun, not to be confused with the Xolchun in the Department of Huehuetenango, lies on the tongue of land formed by the junction of the Rio Blanco and the Rio Negro. A stela, used as the capstone of a tomb, was found in a small temple. Its upper part bore a well carved geometric design. A most unusual structure was an oval, almost circular, platform with seven

terraces. Rio Blanco, a small valley site, shows several periods of construction, and the types of pottery found there indicate a long occupancy. Among the wares noted were plumbate and Utatlan. Xecataloj is a small valley group on the north bank of the Rio Negro about 1.5 km. east of Sacapulas.

It would appear that the well protected hilltop sites are later than the more vulnerable valley sites. Before definite conclusions are reached, however, the collections of potsherds, now in the Institution's office in Guatemala City, must be studied. Probably of significance is the fact that the white-on-red ware occurs only at hilltop sites. Another point is the fact that those in the valleys all have several architectural periods, whereas in most cases the hilltop sites do not. The latter are characterized by much terracing, ball courts with well marked end zones, and split stairways with balustrades. The mounds are usually grouped about a plaza with one or more small platforms in the center. Ball courts in the valley sites lack end zones. At present the two groups that appear most desirable to excavate are Chalchitan and Chutix Tiox: Chalchitan because of its long occupation, its architectural and ceramic sequence, its accessibility, and the availability of good labor at Aguacatan; Chutix Tiox because of the excellent preservation of buildings of various types and because it could conveniently be worked from a base at Sacapulas. Final choice, however, should be postponed until further reconnaissance of the highland region has been carried out.

#### SOILS AND CLIMATIC CHRONOLOGY IN GUATEMALA

KIRK BRYAN

Dr. Kirk Bryan, professor of geology at Harvard University, spent two weeks

in Guatemala studying recent deposits in the neighborhood of Guatemala City and in the Motagua Valley. He also made a short trip to Lake Atitlan and Chichicastenango in order to acquaint himself with the more westerly highlands and ash basins.

The city of Guatemala is built in a wide valley dissected by broad, deep gulches (barrancas) and bounded by hills and mountains. It lies in the divide between drainage to the Pacific and drainage to the Motagua River and thence to the Atlantic. The valley floor is composed of tuff that was deposited as successive showers of volcanic ash. The tuff filled the valley near the city to depths of 1000 feet or more. It was also deposited on the hills but was almost immediately washed off into the valleys. Eastward toward the Motagua each valley had a filling of ash successively finer in grain and shallower in depth. As the height of the fill decreases eastward, it appears that concurrently with the filling of the valleys, runoff took place across the body of ash, so that there was a stream grade on the top of the ash of about 4000 feet in 30 miles, or 13 feet to the mile. In the Motagua Valley there is a terrace of waterworn pumice fragments that rises about 200 feet above the present river grade. It seems to be the river-laid equivalent of the tuff fillings of the tributary valleys. One must suppose that enormous quantities of ash were carried by rainwash off the slopes of the hills into the valleys and thence to the Motagua. Here the river transported most of the load into the sea, but was itself overloaded to such an extent that it built up its grade and formed the tuff terrace.

The origin of the ash showers is presumed to be in one or more of the great volcanoes which fringe the southwestern border of the Guatemala highlands. The tuff has not, however, been traced to any

definite source. Toward the end of eruption the rate of fall decreased and became spasmodic. The upper measures of the tuff sequence near Guatemala City are distinctive. A typical section consists of the following members:

	Feet	Inches
Soil, dark brown to black .	0	6-8
Subsoil, dark brown columnar or blocky; in low places, columnar black clay <i>from 1 to 2</i>	6	0
Disconformity, erosion of shallow valley		
Pumice tuff (upper sand or <i>arena</i> )	3	0
Massive decomposed buff-colored tuff ( <i>talpetate</i> )	6	0
Pumice tuff (lower sand or <i>arena</i> )	4	0
Decomposed buff-colored tuff grading down into massive undecomposed tuff ( <i>talpetate fino</i> )	<i>from 0 to 2</i>	6
White to gray tuff	many	feet

The *talpetate fino* is an old land surface in which the previously deposited tuff was decomposed and converted into a massive yellow clayey layer of variable thickness. Over this surface pumice tuff was deposited by fall from the air. The fragments of pumice range up to half an inch in diameter. The material is used as building sand, hence its local name *arena*. The next layer is a decomposed tuff, very massive and compact. It is obviously a subsoil representing a long period of decomposition under a climate wetter than that of the present time. This compact massive material is used in local building as quarried blocks and as a constituent of sun-dried brick. It is therefore well known and is called *talpetate*, a word presumably related to the Mexican *tepetate*.

The overlying pumice tuff is similar in all respects to the lower pumice tuff.

These formations slope gently upward and, in places, extend to the slopes leading to the adjacent mountains. In particular, the upper pumice tuff mantles steep mountain slopes of older rocks along the Guatemala-Lake Atitlan highway as far as Mixco. Near Guatemala City these three formations are eroded in broad shallow valleys, which drain into the deep barrancas. One of these valleys extends from northwest to southwest through the site of Kaminaljuyu. At its lowest points it reaches the *talpetate fino*. The surface soil is dark brown to black, blocky silty clay, or clay. Intensive cultivation by prehistoric and modern people has disturbed the soil nearly everywhere. Also there are numerous borrow pits from which the prehistoric people obtained material for pyramids and other structures. Many of these pits were back-filled with debris, and the area has since been cultivated. It is thus difficult to find truly natural conditions. Obviously, however, the soil was developed only in part by weathering of underlying material. It is usually an unconformable blanket over the underlying formations and has been largely built up by the gradual fall of ash from near-by volcanoes. The soil processes operating on this continually increasing layer have produced the deep humus-bearing subsoil. In the lower areas, where water has stood in the rainy season, the subsoil is a columnar black clay. On better-drained sites it is a blocky silty clay and in places shows fragments of the underlying pumice tuff or *talpetate*.

It appears that the existing climate, with its strong dry season, produces a soil that accumulates calcium carbonate in the subsoil. It is therefore a climate on the arid side. There is a break in the sedimentation between the soil and subsoil and the upper pumice tuff represented by the ero-

sion of the broad valley already referred to. One must suppose that the *talpetate*, which is an old subsoil of the ferric oxide-aluminous type, was formed in a climate wetter than that of the present. This epoch, however, was far anterior to the earliest known culture of the area. As shown by the excavations of the Carnegie Institution, the oldest pottery of the site, when found in undisturbed areas, occurs at the base of the soil just above the jointed clay. In many localities the soil, subsoil, and part of the underlying material—*arena* or *talpetate*—has been excavated. The back-fill may be 3 feet or more thick and may contain pottery of any age. The soil and subsoil appear to represent a continuous period of growth by accretion of wind-borne volcanic dust and of soil formation under a pine-grass cover. The soil phenomena of the remote past, as represented by the *talpetate* and *talpetate fino*, record wetter conditions. Within the period of known prehistoric occupation no detectable change in climate is indicated by the soils.

#### HIEROGLYPHIC AND HISTORICAL RESEARCH

S. G. MORLEY

Dr. Morley left New Orleans for Merida, Yucatan, Mexico, on November 7, 1944, returning therefrom on May 3, 1945. He spent the summer at Santa Fe, New Mexico, his usual summer headquarters, where Dr. E. L. Hewett, Director of the School of American Research and the Museum of New Mexico, very kindly placed at his disposal office quarters in the Palace of the Governors at Santa Fe, now the Museum of New Mexico. He will return to Yucatan at the beginning of November.

Dr. Morley has devoted the year to two principal research activities: preparation of the Maya hieroglyphic dictionary, and

work on the Maya chronicles in the Books of Chilam Balam.

For work on the hieroglyphic dictionary, a full-time draftsman, Mr. Isaac Esquiliano, of Merida, has been continuously employed for the past three years, drawing the individual glyphs of the Maya stone, stucco, and wood inscriptions under Dr. Morley's direction and supervision. During this period Mr. Esquiliano, a Mexican of mixed Spanish and Maya descent, has developed a very high degree of skill in drawing the Maya glyphs.

At the beginning of this enormous task it was decided to draw first all the glyphs of known meaning, and later those of unknown meaning. Further, in order to facilitate accurate representations, it was decided to concentrate on one glyph at a time, drawing all known occurrences of this particular glyph before proceeding to another. In this way, in the case of partially effaced and badly eroded glyphs, the draftsman would have the benefit of previous experience and familiarity with better-preserved examples of the same glyph.

The first section of the dictionary is thus devoted to the Initial Series introducing glyph, a highly important character in the Maya inscriptions, which not only stands at the head of most inscriptions where it occurs, but whose principal element indicates the name of the patron deity of the Maya month in which the accompanying date falls. This first section is about finished, barring a few odd examples of this sign, chiefly in inscriptions from Campeche.

The next eight sections of the dictionary are being devoted to the different examples of glyphs G and F of the Initial Series and to the six different signs of the Supplementary Series—glyphs E, D, C, X, B, and A—all of which deal with the moon.

Of these, the examples of glyphs E, D, C, and X are also nearly completed.

The drawings of the different occurrences of glyph D have brought to light important new variants and have made possible a number of corrections in decipherment of the corresponding moon ages expressed by that character.

With the cumulative experience gained in repeatedly drawing the same glyph, we have been able to get more out of partially effaced inscriptions than was formerly possible, and although only a beginning has been made, the project may be said to be off to a good start.

The Maya chronicles project deserves a brief word of introduction. There have been preserved in certain native Maya manuscripts known as the Books of Chilam Balam, which are written in the letters of Spanish script but in the Maya language, five chronicles or rescripts of Maya preconquest history. These chronicles are of varying degrees of merit, and there is strong internal evidence that three of them have been copied from a single source, probably an ancient Maya historical manuscript in the hieroglyphic writing, the original of which is now either lost or destroyed.

These five chronicles contain practically all that has survived on the documentary side (i.e., as opposed to the stone, stucco, and wood inscriptions) of ancient Maya history. Laconic as the chronicles are, they nevertheless present a fairly accurate picture with a solid chronological background of the main events of Yucatan history from the early fifth to the late seventeenth century; and, as primary historical source material of the very highest importance, they have long merited the exhaustive and critical study now being given them by Dr. Morley and Dr. Alfredo Barrera Vasquez.

Dr. Barrera Vasquez, now working under a grant from the Colegio de Mexico but having formerly held both Guggenheim and Rockefeller fellowships, has been collaborating with Dr. Morley on a definitive translation of these Maya chronicles into both Spanish and English, and on an interpretive study of their contents.

For the past decade, under the auspices of the above agencies and others, Dr. Barrera Vasquez has been devoting a major portion of his time, first, to making a reconstructed text, filling the lacunae in one chronicle from another and including all variant versions; and, second, to translating the original Maya into Spanish. For the past two years he has spent a month in Yucatan each spring working with Dr. Morley on this investigation. The Barrera Vasquez reconstructed Maya text of the chronicles has been translated directly into English, which language, it has been found, renders the original Maya more exactly than does Spanish. Dr. Morley has written a commentary on the chronicles, incorporating therein the results of his own epigraphic studies during the past thirty years in so far as the latter concern the course of ancient Maya history in the northern half of the Yucatan Peninsula.

The history of Yucatan, as set forth in the Maya chronicles, begins with the discovery of the province of Ziyancaan Bakhalal (the region around the modern Lake Bacalar in southeastern Yucatan) by a group of ancient Maya called the Itza, probably proceeding from some Old Empire site in what is now northeastern Peten, Guatemala, in 9.0.0.0 8 Ahau 13 Ceh of the Maya era, or A.D. 435, and closes with the fall of Tayasal, the last Itza capital, in central Peten, in A.D. 1697, more than twelve and a half centuries of documented Maya history.

## HIEROGLYPHIC RESEARCH

J. E. S. THOMPSON

In the previous report a brief description was given of a new approach to the problem of the decipherment of the Maya hieroglyphs. This method, which involves comparison of glyphic texts with the content of the Books of Chilam Balam, continues to yield interesting results.

In the various Books of Chilam Balam occurs the expression *u xocol haab ti lakin*, "the count of the year to the east," and one may safely assume that similar phrases involving the other world directions were current in Yucatan in the sixteenth and seventeenth centuries. In the hieroglyphic texts of the monuments, the four world direction glyphs are frequently followed by a glyph which consists of an element previously identified as a symbol for counting, and the sign for year. The whole is surmounted by a well known superfix of unknown meaning. There can be no doubt that these pairs of glyphs mean "To the east [north, west, or south] the count of the year." The whole supplies a close parallel to the Books of Chilam Balam save that the world direction is given first, not last.

A problem which has vexed Maya archaeologists for some fifty years is that of the meaning of the "spectacle glyph" which is attached to month signs on occasions which can be proved arithmetically to fall the day before the first day of a month. This sign has been generally read as zero. There are two serious objections to this reading. First, signs with a meaning approximating that of zero are known, but are never substituted for the spectacle glyph. Secondly, the spectacle glyph is combined with the winged Cauac (the haab or year sign), which, if the interpretation as zero were correct, could only mean zero approximate years. There are

cases, however, where this glyph occurs with dates which end in 13 approximate years. The interpretation is thus obviously at fault.

In the Books of Chilam Balam one frequently finds the phrases *u cutal Pop*, *u cutal Uo*, etc., "the seating of Pop," "the seating of Uo," etc., set opposite the first day of each month. On page 7 of the Chilam Balam of Tizimin is the expression *ti cutal ti tun*, "at the seating of the approximate year." Interpretation of the spectacle glyph as "the seating of" fulfills all the demands of the various contexts, and agrees with Maya phraseology. This interpretation led to the identification of two new glyphs, variants of the spectacle glyph, which record whether the addition of a distance number leads to the end of a tun or merely to an odd day. The glyphs must mean respectively "[leading] to the seating of the tun" and "[leading] to the seating of the day." More and more evidence accumulates that the hieroglyphic texts closely parallel the spoken word.

Little success has hitherto attended efforts to interpret affixes, and variations in those attached to glyphs of known meaning have for the most part been ignored, or dismissed as artistic variations. As an example of slight variations in meaning which they reflect, one might cite the three common suffixes of period glyphs. The geometric forms of the katun and tun usually stand on three small circles when these glyphs occur in Initial Series or as period endings. When these glyphs (and other period glyphs) are used as distance numbers, the suffix takes the form of two or three circles between two inverted crescents. Thus, if one finds a period glyph with this form of suffix, one knows that it is part of a distance number. Rarely, the simple suffix of three circles is retained, and the suffix indicative of a distance number is placed beneath it.

A rare suffix, the "bundle" element, is used with the katun and tun only to record anniversaries; that is to say, the completion of a number of tuns or katuns from some important date that is not a tun ending. An example of this is on Lintel 3, Piedras Negras. The Initial Series 9.15.18.3.13 is followed by the katun glyph with a "count" prefix and the bundle suffix. This date is precisely one katun later than a date prominent at Piedras Negras.

The suffix with three circles may be ornamental, or its meaning must be generalized; the other two suffixes are indicative of the way the periods are being used. There are somewhat similar distinctions in the Books of Chilam Balam.

The Maya language has a great number of numerical classifiers, each object or group of objects having its classifier. In English there are a few such numerical classifiers, e.g. head of cattle, loaves of bread, sheets of paper, but the system is with us vestigial. The Maya of Yucatan used *te* as a numerical classifier *inter alia* with years and months. In the hieroglyphic texts there is a small prefix which is sometimes placed between the numeral and the period or month glyph, but which never occurs with day signs. The fact that it sometimes appears as a suffix of head variants of numerals shows that it is connected with the number, not the period or month sign. It almost surely corresponds to *te*. This surmise is further strengthened by the absence of the prefix from day signs, since in spoken Maya the numbers with day names do not take this classifier. Its absence or presence seems to depend on the space available. It is most frequent with low coefficients, where its presence serves to prevent undue distortion of the accompanying glyph; it is almost unknown with high numbers.

The normal work of identification of

glyphs has made some progress. Among new glyphs recognized is a rare head variant of the introductory sign to the distance number, there being a very fine example on Temple 11, Copan. A section of the Dresden Codex has been found to treat of the burner period, prominent in the Books of Chilam Balam. Several new readings of dates have been made in addition to those published in various papers during the period covered by this report.

Mr. Thompson is now engaged in a comprehensive survey of Maya epigraphy. The first volume of this study should be completed during 1946.

#### SOCIAL ANTHROPOLOGICAL RESEARCH

ROBERT REDFIELD AND ASSOCIATES

No notable single accomplishment marked the advance made in social anthropological research of the Division during the past year; no outstanding discovery in the field is to be reported; and no new unit of investigation was begun. The members of the group were engaged in terminal or transitional activities. Dr. Redfield made a short visit to Yucatan and to Guatemala; in Yucatan he reviewed the circumstances that would attend a proposed restudy of Chan Kom, one of the Yucatecan communities studied a decade ago; and in Guatemala he carried forward, in consultation with members of the staff and with representatives of the new government of the Republic, various pieces of business incidental to the Division's research program in that country. Dr. Tax's time was borrowed in large part by the University of Chicago; nevertheless, for Carnegie Institution he brought nearer completion a nontechnical book on the Indian culture of Panajachel. Sr. Antonio Goubaud concluded a period of special employment, and completed a monograph containing the results of the study of diet in

rural Guatemalan communities which he carried on in the field in 1944 with the assistance of Sr. Juan Rosales and Sr. Agustin Pop. Sr. Alfonso Villa Rojas prepared for microfilm reproduction his extensive notes on Tzeltal communities of Chiapas, and in June came to Chicago to write comparative monographs. The publication, during the year, of Sr. Villa's book *The Maya of east central Quintana Roo* provides the student with the last expected monograph resulting from the Yucatan project, the first of the two research programs carried on by this group of workers, and so brings this first project to a close, while the Guatemalan project is still in progress.

The brevity of this annual report provides opportunity here to review what has been done during the past fifteen years.

By 1930 the Institution had already for many years been carrying on researches in Maya archaeology. In that year, there was initiated a new program in which problems of the Maya area were to be attacked by specialists representing many kinds of scientific interest. Ethnology was included, and Dr. Redfield formed a plan to study the living people of Yucatan. Because the Maya of Yucatan are all much the same in language and in native custom, a project was proposed, and carried out, to investigate four communities chosen to represent different degrees of exposure to modern urban influence. The project was so conceived as to serve two interests: that in the ethnography of the Maya, and that in the effects of contact with modern civilization of simpler and more isolated societies. The program was realized in every particular except that a promised publication on the city of Merida was not produced. There were published: a monograph on a peasant village (*Chan Kom, a Maya village*, Publication 448, 1934); another on a tribal community (*The Maya*

*of east central Quintana Roo*, Publication 559, 1945); publications on a town of mixed population and marginal in character to village and city (*The folk literature of a Yucatecan town*, Publication 456, Contribution 13, 1935, and *Disease and its treatment in Dzitas, Yucatan*, Publication 523, Contribution 32, 1940); and, in 1941, a summary and concluding volume expressing the more general conclusions of the study (*The folk culture of Yucatan*, University of Chicago Press).

This project had the following principal results. Sources of information on the present-day Yucatec Maya were provided that exceed in both quantity and quality everything else on the subject that had previously appeared or has since been published. The ethnography of the region was assembled in a single synthesis, in *The folk culture of Yucatan*. The student of Maya history was provided with a full account of the present-day pagan cult, including texts of prayers. It was fairly well established that the culture of Quintana Roo is a reintegration of elements of custom both pagan and Christian, and it was shown that processes of culture growth which move toward consistency operate indifferently on European and on Indian elements. From ethnographic facts almost exclusively, a historical hypothesis was offered as to the course of development of conventional attitudes between racial groups and status groups in the peninsula. For what was probably the first time, a study of a regional American Indian field was (virtually) opened with a project directed by concepts and questions of general interest to students of society and of social change and was carried through to completion. Conceptions and hypotheses as to the natural association of certain characteristics of human living in isolated folk societies, formed by earlier writers, were restated and clarified, and

the power of these ideas to guide the acquisition of new knowledge was demonstrated in terms of a large body of well reported fact. A number of general propositions as to society and its changes were enunciated and given some support from this body of fact. Interdependence between heterogeneity of population and the secularization of life was demonstrated for this case, and it was shown that in Yucatan religion has tended to pass over into magic. The role of sorcery in expressing the insecurity of a member of a disintegrated society was strongly suggested. These are some of the many conclusions of general interest which were reached.

While the Yucatan project was still in progress, the work of this group was extended into the western highlands of Guatemala, then into the adjoining highlands of Chiapas, and finally into the eastern highlands of Guatemala, so that all parts of America occupied by Maya-speaking peoples, save the Huaxtec area of northeastern Mexico, were included in the field of study. In the development of the Guatemalan investigation, the principal part has been played by Dr. Tax. Beginning in 1934 with Santo Tomas Chichicastenango, Dr. Tax, with or without associates, studied Cakchiquel or Zutugil communities on Lake Atitlan, and made briefer studies of Chorti, Pokomam, and Mam communities in Guatemala, and of Tzotzil communities in Chiapas. To Alfonso Villa fell the task of making studies, of long duration and intensity, of the difficult Tzeltal Indians of Chiapas. In 1942 Dr. John Gillin, of Duke University, became associated with the ethnological program of the Institution, making observations on Pokomam communities in eastern Guatemala. His work there was supplemented by that of Dr. Melvin M. Tumin. Dr. Gillin extended his research

to a non-Maya people, the Xinca of Guazacapan, Guatemala.

The extraordinarily diverse local variations of culture in Guatemala made impossible any such single theme of investigation as had been possible in the relatively uniform Indian country of Yucatan. Dr. Tax accordingly devised and put into effect methods for representative sampling of the area included, and for making verifiable and comparable the reports of the several investigators. In 1934 the *municipio* was identified as the basic unit of study, and principal types of municipios were recognized. In succeeding years outlines were prepared to guide the junior investigators; a survey of eastern Guatemala was made by Drs. Redfield and Tax in which a schedule was worked out for the quick reporting of certain information according to municipios; the preparation of community maps was systematized; a method for comparing local cultures quickly according to sample elements of belief and custom was tested; and a project for the preparation of field notes in more or less uniform manner for microfilm reproduction and general distribution among all research students of the area was put into effect.

The problems guiding the later stages of investigation were developed in the course of the ethnographic exploration. These problems are in part ethnological, in part historical. Dr. Tax is determining the distribution of the principal ethnographic types among the Maya peoples, and is bringing this descriptive classification into comparison with linguistic classifications offered by students of Maya languages. Identification is being made of regions in which certain elements of culture (calendar, pagan fertility rituals, sorcery, and nahualism) are strongly emphasized, as compared with other areas in which these elements are absent or unimportant. Prob-

lems of more general or sociological significance are receiving great attention. The conclusions reached in Yucatan as to the interdependence of individualization and secularization with loss of isolation and homogeneity have been tested and revised in the light of facts from Guatemala. The west highland communities of Guatemala have been recognized as providing an exceptional and important societal type: highly commercial and individualized societies with local cultures and with people maintaining a primitive world view. The lack of dependence of secularization upon technological revolution has been brought to the attention of those who have studied secularization from the history of western Europe alone. Dr. Tax has completed a monograph in which for the first time the economy of a nonliterate farming and trading people has been reported with the facts and figures of cost accounting. He has also written monographs on other aspects of the Indian culture of Panajachel, and monographs by other investigators on Zutugil, Pokomam, Tzotzil, and Tzeltal communities are in preparation.

The studies described above have contributed significantly to the development of social anthropology in Mexico and in Guatemala. It may be claimed that fifteen years ago this sort of research was entirely unrepresented in these two countries, that it is now being effectively carried on in both by their own citizens, and that the work of the Carnegie Institution group has been the chief instrument of this change. Soon after its publication in English, *The folk culture of Yucatan* was issued in Spanish translation; a Portuguese edition is now under discussion. In 1942 Dr. Tax taught for a semester in the National School of Anthropology of Mexico, and then took to Chiapas a group of Mexican students whom he trained in field methods. Certain of these students

then continued field research without direct guidance. In 1943 Alfonso Villa taught in the School, and he too supervised the work of Mexican students in the field. Villa himself had been brought to the United States in 1933 to study anthropology at the University of Chicago. He was followed by Antonio Goubaud of Guatemala. Later Juan Rosales, whose gifts as a field investigator had been discovered by Dr. Manuel Andrade, was also brought to the United States for training; after returning to Guatemala he was sent by the government of that country to the School in Mexico for thorough preparation as an anthropologist.

The Division's work in social anthropology has included many activities marginal to the main lines of investigation, and has drawn within its program many enterprises carried on under auspices other than those of Carnegie Institution. In 1939 Villa participated in a study of the Tarascan Indian carried on for the Mexican government. The work of Sr. Julio de la Fuente in Oaxaca was done partly under the influence of the Carnegie group, and in 1943-1944 he came to Chicago to write under its guidance. In 1944 and 1945 the Institution carried out a study of diet of rural Guatemalans; the results will be published by the government of Guatemala. The students of Drs. Redfield and Tax at the University of Chicago have written monographs on subjects of Middle American ethnology and social anthropology; these papers are in substance contributions to the program of the Institution; they include works on the following topics: the *mayordomía*, the concept of the evil eye, collective and cooperative labor, godparenthood and related institutions, the relations between Indians and Ladinos. Two fellows of the Social Science Research Council have carried on field research in the Maya area under direction

of Drs. Redfield, Tax, and Tumin. There have been edited and prepared for publication half a dozen manuscripts on Middle American ethnology written by persons outside the staff of the Institution. Two of these may especially be mentioned: Charles Wisdom's *The Chorti Indians of Guatemala* (University of Chicago Press, 1940), and Oliver La Farge's *Santa Eulalia* (forthcoming). Finally, it may be mentioned that the very considerable expansion of the program of research on the living Maya has been accomplished without corresponding increase in the budget provided by the Institution. The work has been aided by contributions from other sources, including the Viking Fund, the Rockefeller Foundation, the University of Chicago, Duke University, the Social Science Research Council, the National Institute of Anthropology and History of Mexico, and the government of the Mexican state of Chiapas.

#### HISTORY OF THE MAYA AREA

F. V. SCHOLES, R. L. ROYS, E. B. ADAMS

During the past year additional manuscript sources have been examined and extracted in preparation for studies on the colonial history of Yucatan. A brief review of certain data of interest to workers in other branches of Maya research will be made at this time.

The survival of native religion in post-conquest times, concerning which other materials have been summarized in previous reports, is further illustrated by documents relating to the *visita* of Yucatan made in 1583 by Dr. Diego García de Palacio of the Audiencia of Mexico. In a letter to the Crown dated at the Villa de Valladolid December 26, 1583 (AGI, México, leg. 70), Palacio stated that the practice of idolatry was widespread throughout the entire Valladolid district. At

Tzama and Pole on the east coast and also in the towns of San Miguel and Santa María on Cozumel Island, all the Indians "without exception" were said to be idolaters. At Tzama there had been a "temple of idols" where the Indians gathered to celebrate "festivals, dances, and other ceremonies as in ancient times." We surmise that this place was simply the *popolna*, defined in the Motul dictionary as the "casa de comunidad," where certain dances were taught. In such case, the Indians no doubt had regular temples in the bush, as was true on Cozumel Island (see Roys, Scholes, and Adams, Carnegie Inst. Wash. Pub. 523, Contr. 30, p. 27). This "temple" at Tzama had now been burned, presumably by order of Palacio, and all the more than five hundred idols had been smashed and cast into the sea.

Palacio goes on to state that the common people guilty of idolatry had been given mild punishments, but the caciques, native priests, "and the *maestros* who made the statues (*estatuas*) and figures" had been arrested and would receive more severe punishment; "because in view of the boldness and excess with which they have lived in this sin, it is necessary, in order that henceforth mercy should not give them reason for greater obstinacy, as apparently has been the case up to the present time." The reference to *maestros* (masters, teachers, artisans) who made the idols is of some interest. The word *estatuas* usually seems to mean wooden idols, and Landa gives an account of the making of such figures. Palacio's letter and a supplementary report refer, however, only to clay idols, so in this case the *estatuas* were apparently of this kind.

The prevalence of idolatry on the east coast and Cozumel is not surprising, since the towns of this region were located at some distance from the nearest mission

centers. Palacio's letter states, however, that in towns situated only one, two, or three leagues from the Villa de Valladolid similar conditions prevailed. On one journey outside the villa he had collected 1160 idols, in addition to many others that were destroyed, and he had punished more than 600 idolaters. He had also banished from this area certain "dogmatizers, priests, and *maestros*" of these idolaters.

A supplementary report (Valladolid, 12 diciembre, 1583; in AGI, México, leg. 70) describes some of these 1160 "quiçines," or idols, that had been gathered up. Some were said to be as large as children three, four, and five years old. Others were "figures of men with emblems (*divisas*) of animals on their heads, and others with miters and tiaras and other headdresses of men and women according to ancient custom, which the said Indians were accustomed to wear . . . in their sacrifices, festivals, and rites when they performed their idolatry."

Figures of men with "emblems of animals" on their heads are familiar in the Maya codices and on the monuments. Some of the animal headdresses have been thought to be carved wooden helmets. Clay figures of this kind were probably gods, including deified men. The "miters" suggest Mexican tradition, and figures with such characteristics may have represented deified lineage ancestors, old invaders (?). The significance of "tiaras" in the case of gods is not clear. Gem-studded bands seem to be found on both gods and warlike men at Chichen Itza: on caryatids, "chac-mools," and relief figures. The first Spaniards found gold headbands in chests in the temples of northern Yucatan and obtained others in Tabasco. We are inclined to associate them principally with deified heroes or lineage ancestors, but they may have a wider scope.

The report describing these idols also

mentions figures of "leones," "tigres," and dogs, and "temples (*cues*) of different plans and forms." The pumas and jaguars of architectural sculptures evidently represent the military orders, but here we presumably have actual gods. The "leones" may have represented the war god, Citchac-coh ("father-red-puma"). The Book of Chilam Balam of Chumayel mentions a Chac-bolay-balam (chac-bolay means "tigre bermejo y bravo") and a Chac-bolay also figures in the Tizimin manuscript. We find no mention of dog gods in the colonial literature, Maya or Spanish. Figures of dogs are familiar, however, in the codices, and in the Dresden 7a a dog appears in a long row of deities. Dogs were also a favorite sacrifice, and Landa tells of offerings of clay dogs with bread on their backs. The figures mentioned in this 1583 report may have been something like votive offerings, if they were not idols of a dog god.

Despite the punitive measures imposed by Dr. Palacio, idolatry continued to exist in the Valladolid area and other parts of the province (see data recorded in previous reports). A letter of Bishop Vázquez de Mercado dated May 2, 1606 (AGI, México, leg. 72) records that "Indian idolaters were daily being discovered in various towns of this diocese." During a visitation made by the bishop in the Valladolid district "there were discovered and punished more than 80 Indians who, in gangs (*cuadrillas*), assembled in different pueblos to perform the said idolatries." Moreover, a beneficed priest in that area had recently sent a report of 56 other idolaters whom he had found in the towns of his benefice. They had clay idols "de malísimas figuras . . . que a unos llamaban Dios Padre, a otros Dios Hijo y a otros Dios Espíritu Santo y Santa María y a otros muchos nombres de santos y santas como a ellos les parece, teniendo los dichos sus

sacerdotes que hacían las ceremonias y sahumerios cuando todos se juntaban a idolatrar."

This reference to clay idols called God the Father, God the Son, God the Holy Spirit, Holy Mary, and other names of saints is reminiscent of a report by Francisco Hernández in 1545 (see Las Casas, *Apologética historia*, ch. 123; Saville, *Mus. Amer. Indian*, *Indian Notes and Monographs*, vol. 9, no. 3). Hernández reported that God the Father was Içona (Itzamna); the Son was Bacab, son of a virgin named Chibirias (Ix-chebel-yax, according to Seler); the Holy Spirit was Ekchuuah. Cf. Tozzer, *Landa's Relación* (Cambridge, 1941), Syllabus, page 310. Tozzer also discusses a report of 1913 by Bartolomé del Granado Baeza which records saint names for three of the Pauahtuns. The bishop's letter of 1606 indicates that the naming of certain gods by the names of saints started early, and it continues to the present day (see Gann, *Bur. Amer. Ethnol. Pub.* 64, pp. 46-47). Deities with saint names appear, however, to have retained their pagan functions and characteristics. The bishop, of course, was well advised in condemning the practice.

The bishop's letter of 1606 was written in response to an inquiry from the *Audiencia* of Mexico, which in turn was prompted by a royal cedula of April 24, 1605, asking for information concerning the practice of idolatry in Yucatan "and why it is more prevalent in that province than in others." The bishop stated that it was not because of lack of instruction in the elements of Christian faith and doctrine, for he had personally examined some of the idolaters and they had given adequate answers to all questions of faith. It was his opinion that there were two major causes for the continued practice of the native religion. The first was the mild punishment that had been im-

posed, even in the case of the caciques and native priests. It is well known, of course, that Landa used stern measures during the investigation of 1562. Although the latter investigation put an end to the practice of human sacrifice, the severe punishments and torture employed by Landa not only caused serious unrest in Yucatan, but also aroused unfavorable criticism in high Spanish quarters. Consequently, in later years the clergy tried another tactic, employing public or private admonitions or some form of mild punishment in dealing with the idolaters. As already noted, Dr. Palacio proposed to deal more harshly with the caciques and native priests than with ordinary offenders, but in general the local authorities apparently tried to cope with the situation without resort to stern measures. But this method had failed, for, as the bishop said, Indians who had been punished on other occasions had continued their idolatrous practices, "the cause of which, I understand, is the mild punishment they have received for this great offense against God." "It appears to me therefore that it would be suitable for your Majesty to order . . . that the leaders and priests, especially those guilty of second offenses, should be given the most severe penalty."

The second cause noted by the bishop was the lack of compact Indian settlements, "because in all this diocese there is no well formed town; on the contrary, each household lives by itself scattered among the bush in such a way that a town of 100 citizens may occupy a district of half a league because of the scattering of the houses." This statement probably exaggerated the situation, but it indicates, nevertheless, that the policy of congregating the Indians into compact towns instituted by Tomás López in 1552 had not been effectively carried out, or that during the later decades of the sixteenth century

there had been considerable laxity in regard to town organization and control. To remedy the situation the bishop recommended that effective measures should be taken to reassemble the Indians "in streets and squares surrounding the church, so that in this way there would not be such freedom for their debaucheries and other sins, and so that they will be better indoctrinated."

The *definitorio* (governing council) of the Franciscans also made a statement on the subject which supported the bishop's views. The Franciscans, however, added another point of vital importance: the fact that the Indians of settled towns in northern Yucatan maintained contacts with the "gentiles" of the interior, with whom they carried on trade, selling them such articles as salt, knives, axes, machetes, and similar goods. "As a result of this trade and commerce they learn the idolatry and ancient rites which they may have forgotten as a result of evangelical teaching." The Franciscans might also have added that the bush country of the interior was also a convenient place of refuge for groups of Indians who, for one reason or another, wished to escape Spanish control, civil or religious. Throughout the entire colonial period the Spanish authorities sought to bring the interior under effective control, but in the main they never achieved more than temporary success. The bush and forests of central and southern Yucatan were always a haven for Indians who wished to escape oppression, or to live according to the old native customs.

During the past year Mr. Roys has continued and nearly completed the transcription of a Maya manuscript known as the Ritual of the Bacabs. This document of 237 pages consists mostly of medical incantations, although some directions for treatment are also included. The last page

is written on the back of a printed Indulgence dated in 1779. Although much of the manuscript is not difficult to read, on many pages there are water stains or the writing has faded, so it has been necessary to make a preliminary study of the more legible parts in order to complete the transcription.

In spite of the late date of the manuscript, these incantations are practically free from European influence. With the exception of an occasional "Amen" and very rare mention of the Spanish Dios, no reference to the Christian religion has yet been found. "The four gods, the four Bacabs," who were prominent deities, are often invoked, and it is from these that the manuscript was given its title by its discoverer, William Gates. The Pauah-tuns, believed to be wind gods, are barely mentioned. As might be expected, the Maya goddess of medicine also plays a prominent part; but she is usually cited in a twofold phase, as Chacal ("the red") Ix Chel, and Sacal ("the white") Ix Chel. Only once have we noted an Ekel ("black") or a Kanal ("yellow") Ix Chel. The distinction may indicate a reference to the four world quarters, to which these colors were ascribed.

A number of other deities are invoked or cited. We find the thirteen sky gods known as Oxlahun-ti-ku, and the nine deities of the underworld, Bolon-ti-ku, which are occasionally mentioned in the Books of Chilam Balam, but the others appear only rarely in colonial Maya literature.

Several times there is an invocation to the little-known Colop-u-uich-ku. The name strongly suggests a sun god, and in the Vienna dictionary he is described as "the principal god . . . from whom they said all things proceeded and who was incorporeal, hence they made no image of him." We also find a mention

of Kin-ich-kak-mo ("sun-eyed fire parrot"), a more familiar deity associated with the sun.

The sky god Itzamna, usually considered the head of the Maya pantheon, also appears in these incantations. We read of "the home of the father (or lord?) of the sun, Chac Ahau Itzamna." This name could be translated as "great (or red?) lord Itzamna." There is an obscure reference to "the thigh of Hun Itzamna," and a Kanal ("yellow") Itzamna is also cited. Associated with Itzamna are the iguana (*huh*) and another lizard (*itzam*).

Frequent accessories, apparently in the ceremonies which accompanied these incantations, were a green human figure of wood (*yax uinicil te*, or *che*) and a similar one of stone (*yax uinicil tun*). In the treatment of a sore foot, we infer that changing the dressing is symbolized by what is called changing the bed covers of these figures. These coverings are alleged to be the tails of the quetzal (*yaxum*) and the macaw. In this manner, states the healer, "I remove the great cause of pain."

The disease is often personified and is informed that 4 Ahau, or sometimes 1 Ahau, was the day of its birth. The healer addresses it with authority and threatens it. To one disease he says: "Thus I throw you down. I am your mother, I am your father; I cast you into the midst of the sea." To another he claims a similar relationship and condemns it "to the evils of the underworld."

Many of these incantations have a genuine poetic quality and abound in graceful figures of speech. In treating various feverish skin eruptions the healer states that he is cooling the throbbing pain with his red, white, and black fountains and with cenotes, forest ponds, and hailstones of these colors.

Some of the incantations are ordinary

magic, such as charming a scorpion or cooling water while it is on the fire. The most interesting and poetical is that of the birth of the spider, which has been published by J. E. S. Thompson (Carnegie Inst. Wash. Pub. 509, Contr. 29). Here a green wooden spider and one of stone appear to take the place of the human figures in the other incantations.

The language of this manuscript is often obscure, and a complete translation will be very difficult.

In view of J. E. S. Thompson's approach to the problems of hieroglyphic writing by seeking parallels between such texts and certain passages in the colonial Maya literature written in European script (Year Book No. 43, pp. 172-173), we have searched the latter for chronological expressions or figures of speech which might easily lend themselves to pictorial representation. Their precise significance is not always clear, since they have come down to us mostly in manuscripts of the eighteenth century. By this time the copyists, who occasionally interpolated their own comments, had forgotten or become confused over some of the details of the old calendar system. We even find the katun explained as being a period of twenty-four years. The following excerpts have been selected from a series of yearly prophecies covering twenty years, which are recorded in the Books of Chilam Balam of Tizimin and Mani. They are given here as examples of phrases which we might expect to find expressed in hieroglyphic writing, but it does not, of course, necessarily follow that such will prove to be the case.

These prophecies begin with a statement of "the taking of *lac* of Katun 5 Ahau." The *lac* today is a shallow bowl, and the term has also been defined as a clay idol, but we infer it was an effigy bowl, possibly an incense burner. There

are occasional references to the "burden" or "charge" (*cuch*) of the katun. In one of these the number 5, the coefficient of the day for which the katun is named, is said to be its burden; and we are reminded of a full-figure Initial Series inscription at Copan, although here it is not the coefficient which is represented as being the burden.

One of the year bearers is "the day of setting in order the bird (*ch'ich'*) of the katun." Since we find elsewhere the "bird" of the day closely associated with its augury, the term probably has the same meaning for the katun.

For the tenth year there is a reference to the fan and bouquet of the ruler, presumably the god presiding over the katun, who "points his finger at the day he takes over his government." He is set up at his cup (*luch*), on his throne or dais (*dzam*), his mat (*pop*), and his seat (*kanche*); and this establishment of the lord of the katun was very probably a chronological ceremonial.

For the year in which the last hotun begins we find a reference to the "binding of the burden of the katun." Here, instead of the coefficient, the burden appears to symbolize the destiny of the katun, which consists mostly of various misfortunes. This meaning is confirmed by the Motul dictionary. In the following year the burden is bound again, and the "rulers of the land" are said to be blindfolded. Whether earthly rulers or gods are meant is a little uncertain. Elsewhere in these Maya manuscripts the blindfolding of a deity appears to symbolize the loss of his power. Here it seems to indicate the approaching end of the katun, an event which concerned both gods and men.

At the end of these prophecies we are told that on a day 13 Oc "the katun is paced off" (*u chek oc katun*). This is evi-

dently a play on the day name Oc, which can also mean "foot." In the Codex Pérez, however, the "pacing off" of the katun appears to begin on the day Oc, which falls just ten days before the end of the katun.

Mr. Thompson has noted a danger in this approach because of the uncertainty as to the language of the people who carved the inscriptions. A large proportion, though by no means all, are found in areas where either Yucatecan Maya or one of the Choloid languages was spoken at the time of the conquest. The latter comprise Chontal, Chol, and Chorti, and it has been shown that these three are hardly more than dialects of the same language, which, indeed, the sixteenth-century Spaniards considered them to be (Thompson, Amer. Anthropologist, n. s., vol. 9, pp. 584-603; Scholes and Roys, Acalan-Tixchel, in preparation).

Philologists have established a close relationship between Yucatecan Maya and Choloid, and it has long been known that for a person who knew one, the other was not very difficult to learn. Nevertheless, how close the resemblance was for practical purposes is a matter of some consequence. It is certainly closer than would appear from the comparative word lists that have been published, and to form some idea of this a comparison has been made between Becerra's large vocabulary of Palenque Chol (*Anales del Museo Nacional de Arqueología, Historia y Etnografía*, quinta época, vol. 2, pp. 249-278) and the Yucatecan Maya. Many words are almost identical and have the same meaning in both languages. In other cases the words are the same, but they have a slightly different meaning. Becerra's *bush* is defined as an ordinary gourd (*calabaza*), whereas the Maya *bux* (pronounced the same) in northern Yucatan was a small

wild variety. There are also numerous instances where a Maya would understand a Chol term in spite of its difference from the word used in northern Yucatan. In Maya a skull is *tzek*, and although the Chol equivalent is *bukel jol*, it resembles the Maya *baac* ("bone") and *hol* ("head"). Similarly, the Chol word for heel, *yitkok*, would be understood by a Maya as meaning the bottom of the leg or foot. There are certain sound shifts, but it seems unlikely that they would cause much difficulty. For consonants the two most frequent shifts are those in which Maya *can* ("serpent") and *che* ("trec") correspond to the Choloid *chan* and *te* or *tie*.

A comparison of the first 400 words of Becerra's Chol vocabulary with their various Maya equivalents or near equivalents suggests strongly that a Yucatecan would either understand or have an approximately correct idea of the meaning of 50 to 60 per cent of them. Available Choloid texts are few and brief except for the long Acalan Chontal narrative, which contains a very considerable variety of subject matter. Here the sentence structure is very similar to that of Yucatecan Maya. The tentative conclusion of this inquiry is that whatever its origin, Maya hieroglyphic writing was probably adequate for the use of both these linguistic groups.

#### UNITED STATES HISTORY

LEO F. STOCK AND JOHN J. MENG

It was expected that this report would announce the completion of the manuscript of volume VI of the *Proceedings and debates of the British Parliaments respecting North America*. The amount of material bearing upon the Seven Years' War, however, is so voluminous and the necessary annotations are proportionately so time-consuming that there still remain three or four months of work before the

volume will be ready for printing. The questions at issue during this significant period, which preceded and which in large measure created the immediate conditions leading to the American Revolution, will make this volume an important one.

This may be the final volume of the series to be sponsored by the Institution. After thirty-five years of service, Dr. Stock's formal connection with the Division of Historical Research terminated July 31, 1945. In view of the extensive use so far made of the series in graduate schools and by writers in the field of colonial history, and because of the amount of unprinted sources that have been collected for the period ahead, the editor will continue to give as much time to this work as the pursuit of postretirement interests will permit.

Dr. Stock also intends to complete the orderly arrangement of the files of the former Department of Historical Research. Their value was illustrated in the correspondence between Viscount Bryce and Dr. J. Franklin Jameson which was printed in the January 1945 issue of the *American Historical Review*.

As in previous years, Dr. Stock has replied, for the Division, to many inquiries of historical nature, and has rendered other aid to students who came to Washington.

Volumes III and IV of the *Guide to materials for American history in the libraries and archives of Paris* are now complete in manuscript for anticipated publication when present printing and binding difficulties have been eased. Volume V, the final one of the series, deals with the colonial archives and is now in preparation. The work is being done by John J. Meng under the general direction of Waldo G. Leland.

Comforting information relating in part to the future usefulness of the *Guide* was

received during April 1945 from M. Abel Doysié in Paris. M. Doysié, one of the collaborators in the preparation of the publication, wrote concerning the Foreign Office archives: "The building was burnt, but the archives are safe though not available yet." Doysié himself is once more engaged in historical research, after several months in a German concentration camp and the destruction of his home by bombing.

#### HISTORY OF SCIENCE

GEORGE SARTON

*Introduction to the history of science.* Most of Dr. Sarton's time was devoted to the final revision of the manuscript of volume III and to proofreading. Thus far 421 galley proofs have been read, more than a third of the total but less than half. So large and complex is this work that at least another year will be needed to complete the proofreading and indexing.

*Editing of Isis.* The publication of *Isis* has been considerably slowed up, because the Harvard University Printing Office is short of labor and is obliged to do the University work first. Two numbers only have appeared (nos. 100 and 101), and volume 35 (1944) is not yet completed, the last part (no. 102) being now in page proof. Numbers 100 and 101 include 12 main articles, 17 shorter notes, 23 reviews, 830 bibliographic items, and are illustrated with 4 plates and 29 figures in text. Since its foundation in 1913 *Isis* has never been smaller. Editorial work has been continued, however, by Dr. Sarton and Dr. Pogo, and a large amount of manuscript is ready for publication as soon as circumstances permit.

From 1913 to 1940 *Isis* had been printed in Belgium. Word has been received from the St. Catherine Press in Bruges that the stock of *Isis* and *Osiris* has been preserved in spite of the fact that other presses in the

neighborhood have been destroyed. Volume 32 of *Isis* and volumes 8 and 9 of *Osiris*, which were being printed in Bruges at the time of the German invasion, will be published as soon as possible. This will not be before 1946 or perhaps 1947.

*Ancient science down to Epicurus.* Four chapters are completed, dealing respectively with the dawn of science, Egypt, Mesopotamia, and the Aegean area.

#### PUBLICATIONS

MARGARET W. HARRISON

Of the three major publications reported in press at the time of last year's review, wartime difficulties in the printing industry have permitted the publication of only one, Alfonso Villa's *The Maya of east central Quintana Roo* (Publication 559), released in May 1945. Beginning with a brief survey of the history of Quintana Roo and ending with a critical bibliography of the War of the Castes and a discussion of historical sources by Howard F. Cline, the book describes the Indian mode of life in the most isolated of the four Yucatecan Maya communities studied by ethnologists and sociologists of the Institution from 1930 to 1936. A second community was reported on by Robert Redfield and Sr. Villa in *Chan Kom, a Maya village* (Publication 448), issued in 1934; and a third by Dr. and Mrs. Redfield in *Disease and its treatment in Dzitas, Yucatan* (Contribution 32 in Publication 523), issued in 1940. The final results of the study became available in Dr. Redfield's *The folk culture of Yucatan*, published by the University of Chicago Press in 1941. The report on the remaining community, Merida, is not yet completed.

Miss Proskouriakoff's *Album of Maya architecture* (Publication 558) has progressed as far as page proof of the text.

The gravure illustrations, the main feature of the publication, have been printed for several months.

*Textiles of highland Guatemala* (Publication 567), by Lila M. O'Neale, professor of decorative art at the University of California, Berkeley, is ready for binding. The text and gravure illustrations are printed; the line cuts are undergoing final revision.

Under the joint authorship of France V. Scholes and Ralph L. Roys, the manuscript of *Acalan-Tixchel: a contribution to the history and ethnography of southwestern Campeche* (Publication 560) has nearly reached completion. It is expected that the text will be ready for the printer by early fall of 1945.

*Excavations at Kaminaljuyu, Guatemala* (Publication 561), by A. V. Kidder, J. D. Jennings, and E. M. Shook, with technological notes by Anna O. Shepard, is now in galley proof. This book is a detailed account of the excavation of two mounds, in each of which were found several superimposed structures and richly stocked tombs. The grave furniture, fully described and illustrated, contained a large number of important objects which served to establish chronological relations between the local Guatemala highland culture and several other major cultural developments in the Maya area and in central Mexico.

J. Eric S. Thompson has finished the manuscript of *An archaeological reconnaissance in the Cotzumalhuapa region, Escuintla, Guatemala*, which will form Contribution 44, the first paper in volume 9 of Contributions to American Anthropology and History. This paper contains an analysis of the historical ac-

counts of the Indian tribes on the Pacific littoral of Guatemala and a comparative study of the sculpture found in that area.

To the second volume of Notes on Middle American Archaeology and Ethnology have been added eighteen numbers during the year. Half of these, listed in the bibliography at the end of this report, have come from members of the staff, the Misses Proskouriakoff and Shepard and Messrs. Kidder, Morley, Roys, Smith, and Thompson. Specialists outside the Institution contributed the remainder: *Archaeological finds near Douglas, British Honduras* (no. 40), by A. Hamilton Anderson and Herbert J. Cook; *Ixte weaving at Chiquilistlan, Jalisco* (no. 42) and *Worked gourds from Jalisco* (no. 43), by Isabel T. Kelly; *The graphic style of the Tlalhuica* (no. 44), by R. H. Barlow; *The Venus calendar of the Aztec* (no. 46), by R. C. E. Long; *Costumes and wedding customs at Mixco, Guatemala* (no. 48), by Lilly de Jongh Osborne; *Moon age tables* (no. 50), by Lawrence Roys; *A second Tlaloc gold plaque from Guatemala* (no. 51), by Karl-Heinz Nottebohm; and *Rock paintings at Texcalpintado, Morelos, Mexico* (no. 52), by M. A. Espejo.

Mrs. Harrison has in preparation the compilation of a dictionary of terms applicable to Middle American archaeology, covering architecture, ceramics, artifacts, and sculpture. The terms are confined to English words and foreign words taken over into ordinary archaeological usage. A preliminary list of tentative definitions will be distributed in mimeographed form to specialists in this field for corrections and additions before final publication.

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